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The International Political Economy of Patent Buyouts*

Amal Ahmad† Dominik Naeher‡ Sebastian Vollmer§

Abstract

The literature on patent buyouts has focused on single-economy settings, where buyouts are welfare improving relative to patents unless there are frictions such as imperfect information or commitment problems. We expand the analysis to a world with two heterogeneous countries featuring different sizes and innovation capacities. Moving to an international setting introduces the tradeoff that buyouts help to reduce monopoly distortion but also eliminate profits from foreign markets. We show that this can rationalize why buyouts are not pursued even in the absence of information and commitment problems, and identify the conditions under which this is harmful to global welfare. Instead, countries in the model rely on a system of global patent protection paired with domestic price subsidies, and only intersovereign transfers can achieve a globally optimal buyout equilibrium. Our results suggest that buyouts are constrained not only by domestic frictions but also by a global public good dimension.

Keywords: Innovation, intellectual property rights, patents, buyouts, global public goods

JEL Codes: F13; H87; L1; O31; O34; O38

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1 Introduction

It has long been acknowledged that patents, while incentivizing innovation, fail to lead to the first best outcome for society because they rely on the distortion-creating incentives of monopoly (Nordhaus, 1969; Wright, 1983; Shavell and van Ypersele, 2001). The monopoly structure generally results in too little innovation (dynamic loss) and in too-high pricing (static loss) relative to the social optimum. One area in which these issues may be particularly salient is global health. Many medicines, including life-saving drugs, are inexpensive to manufacture once innovated, but patents associated with their innovation can generate high prices which limit access to these technologies (Stiglitz and Jayadev, 2010; Quigley, 2015). In addition, the incentive for patent-driven investment in innovation may be too small relative to what is socially optimal, particularly when the global burden of disease falls heavily on poor populations. For example, the latter has been argued to be a major contributing factor to the low private investment in HIV/AIDS vaccine research relative to the disease's high global health burden (Kremer and Snyder, 2006).

Within theoretical economics, a large 'optimal design' literature has explored how patent length and breadth can be structured to limit deadweight loss and the under-provision of innovation, but these losses cannot be eliminated altogether (Rockett, 2010). In practice, and in the case of pharmaceuticals in particular, innovating countries often pursue a mix of intellectual property rights and price subsidies to facilitate production of and domestic access to patented technology (Roin, 2014). This can limit the social losses from underproduction and overpricing to consumers in these countries, but it does not eliminate them, and the effects of imposing patents on consumers in the developing world can be very large (Chaudhuri et al., 2006).

This paper contributes to the theoretical literature exploring why patents, despite creating potentially large social costs, remain the predominant method of incentivizing innovation. We focus on buyouts as a potential alternative arrangement. In a buyout, the government transfers an ex-post reward to the innovating firm in exchange for placing the knowledge in the public domain and for permitting competitive production of the subsequent good.[1] It is straightforward to show that within a single economy, if the government transfers the amount which equates the firm's rewards with the social benefit of innovation, supplanting any monopoly power, it can incentivize innovation and production at the socially optimal level (Wright, 1983; Shavell and van Ypersele, 2001; Galasso, 2020).

Given that perfectly calculated and executed buyouts will always eliminate underproduction and deadweight loss, for the choice between patents and buyouts to be nontrivial

[1]Some papers in the literature term this arrangement a prize or a reward but for consistency we will refer to it as a buyout throughout the paper.

it is necessary that there are costs to buyouts that can obstruct their feasibility and impact their desirability. The literature on buyouts, discussed further below, has emphasized how information problems about the appropriate size of the transfer, or commitment problems relating to the credibility of the transfer from the government to innovating firms, can impede buyouts as an alternative to patents. The implication is that if certain mechanisms can mitigate the domestic information or commitment problem, buyouts would, at least in theory, emerge as a welfare-improving substitute to intellectual property rights for incentivizing innovation.

In this paper, our point of departure is that exploring buyouts from a single-economy perspective leaves out the challenges of instituting buyouts in a world where different countries would benefit from the innovation but possess varying innovation and financing capabilities. Departing from the focus on a single-economy perspective, we tackle the question of buyouts versus patents from an international perspective. Using a stylized exposition of two heterogeneous countries which differ in their size and innovation capacity, we show that concerns about the redistribution of profits emerge as an important determinant of whether buyouts are desirable and to whom, even in the absence of information and commitment problems within the innovating country.

In our baseline model, which builds on Deardorff (1992), and starting from a status quo of globally enforced patents, a Northern monopolist produces innovations and a Southern country cannot imitate production unless the patent regime is removed. The Northern government has the option to maintain the patent globally or to institute a buyout in which the intellectual property rights are eliminated globally. It may also pursue a regime in which it subsidizes its monopolist to produce and sell domestically at the competitive level while preserving its patent for use abroad. This latter scenario is inspired by the practice used in many advanced economies of using price subsidies to facilitate production of and access to drugs, while keeping the underlying monopoly power intact (Roin, 2014). To focus on the redistributional channel, we abstract from any information problems and intra-North commitment problems.

We show that, first, in the choice of patents and buyouts that is standard in the literature, it is now possible that buyouts may be globally welfare enhancing but not pursued even in the absence of any information or commitment problems in the innovating country. This is the case when the degree to which buyouts eliminate Northern producer profits in the South exceeds benefits from monopoly elimination to Northern consumers, in which case the North will pursue a patent regime.

Second, when price subsidization within the North is an option, the North will pursue this option as strictly preferable to both patents and buyouts, even in situations where buyouts would improve world welfare. This is because with subsidies the North is able to eliminate the deadweight loss from patent pricing to its own consumers while preserving patent-based profits generated abroad. While the North as a whole is strictly better off in this regard, the costs to the South can be very large, reducing welfare from a global perspective. Moreover, all three arrangements - patents, buyouts, and price subsidies - are pursued from the standpoint of the North's welfare, and therefore generate innovation levels below the global social optimum. The latter would be a buyout where the research investment maximizes *both* countries' welfares.

Third, only transfers from the South to the North that are budget-feasible and credible will achieve the globally efficient level of innovation. This is because transfers eliminate the key problem identified in our model, which is that the cost of buyouts is borne solely by the innovating country, while both patents and subsidies ensure that consumers abroad pay their share of the innovation cost. At the same time, we discuss why such transfers may not be possible in practice, including budget limitations and frictions in tax financing in the low-innovation countries from which these transfers would have to come.

In addition to this baseline model, we explore two extensions. First, we model a situation of porous borders where (unlicensed) resale of goods is possible from the North to the South. We show that while this reduces the desirability of price subsidies relative to full patents,[2] the key profit distribution concerns impeding buyout feasibility remain intact. Second, we consider what happens when both countries can innovate in different sectors and their welfare depends on the innovation regime in both sectors. We show that both countries will pick price subsidies for their own sector as a dominant strategy. Moreover, depending on the form that the buyout strategy takes, the game may devolve into a Prisoner's Dilemma where both countries are stuck in the subsidy equilibrium even though they would both be better off with a buyout in each sector.

In light of these findings, buyouts of innovations that are useful internationally may be understood as belonging to the category of global public goods, which are notoriously difficult to finance. Since these limitations imply that an altruistic donor may help bridge the gap, we also discuss the relationship between this scenario and proposals such as an Advanced Market Commitment (Kremer et al., 2020, 2022), the Health Impact Fund (Banerjee et al., 2010), and other philanthropic initiatives seeking to expand access to patented products, mostly in the healthcare and pharmaceutical sectors.

To situate our contribution, what follows is an overview of the literature on buyouts as a potential alternative to patents for incentivizing innovation. Most contributions have focused on challenges in a single-economy setup, and particularly on information problems that emerge when the government lacks precise information on the benefits and costs of the innovation (Scotchmer, 1999). In such cases, the information asymmetry may result in a buyout with lower subsequent welfare than patents despite the latter's distortionary

[2] This is because with price subsidies some of the monopoly profit from the South is undercut by the movement of competitively prices goods from the North to the South, while global patent protection prevents this from happening.

effects (Wright, 1983; Shavell and van Ypersele, 2001). Papers have outlined a variety of institutional mechanisms that can mitigate the information problem and improve the optimality of buyouts, depending on the assumptions made about the nature of the problem (Kremer, 1998; Chari et al., 2012; Weyl and Tirole, 2012; Galasso et al., 2016, 2018).[3] In a departure from the information asymmetry literature, Galasso (2020) explores how commitment problems may obstruct the feasibility and effectiveness of a buyout even if the government has perfect information. This would occur if the government is subject to stochastic shocks that may require it to divert resources to an alternative unforeseen investment, and if it faces a limited budget, so that it will not be able to credibly commit to a transfer of the requisite cash rewards to the innovator.

Another literature explores the welfare effects of patent protection versus patent infringement in a world economy, but with no discussion of buyouts. This literature uses trade models to demonstrate how the enforcement of intellectual property rights can be particularly detrimental to the welfare of developing countries. In a simple North-South model where a Northern firm can innovate while a Southern firm can imitate its innovation if patents are not enforced by the government of the South, the interests of the North and South will generally conflict, with the South benefiting from the ability to imitate technology and the North harmed by it (Chin and Grossman, 1988). Similar conflicts of interest arise in situations where the Northern government can choose whether or not to require protection in the South (Deardorff, 1992), where the decision to invest in R&D in the North is not one-off but dynamic (Helpman, 1993), and where both Northern and Southern firms can innovate, to different degrees, and intellectual property rights (IPR) protections are decided simultaneously as they trade (Grossman and Lai, 2004). Careful empirical measurement of welfare effects on the South of patent protection is limited, with the exception of Chaudhuri et al. (2006) who construct demand curves to estimate large negative effects in India of TRIPS-triggered protection of antibacterial medicines.

Our paper therefore bridges between the literature on patents versus buyouts, which focuses on single economies, and the trade literature on patent protection versus patent infringement in an international setting. It demonstrates how the redistributive concerns highlighted by trade models can be relevant to the buyout literature, and outlines how they can obstruct the implementation of globally welfare enhancing buyouts (in the absence of

[3]Specifically, Kremer (1998) argues that if competitors have information about private industry costs, the government may be able to elicit that information indirectly through an auction. Chari et al. (2012) and Galasso et al. (2016) examine how the planner can use observable market signals over time to bridge the information problem, when market demand is and is not manipulable by the innovating firm, respectively. Weyl and Tirole (2012) show that an arrangement with less than full monopoly is optimal when market power can be used to screen willingness-to-pay in the presence of multidimensional private information. As a variation on the information problem, Galasso et al. (2018) show that if innovation effort is multidimensional and cannot be fully measured and therefore contracted upon, combining patent rights with cash rewards may be preferable to placing technologies in the public domain.

feasible and credible channels for interstate transfers).[4]

A few qualifications are in order. Industrial structure is simplified by studying one-off R&D investment decisions, abstracting from potentially dynamic innovation processes and broader general equilibrium effects. To solve the model analytically, we also employ a specific functional form for the demand and surplus functions. We discuss these and other simplifying modelling choices in the paper. We also outline considerations, omitted from our model, which would limit the feasibility of intersovereign transfers for resolving the global public goods problem.

The paper is structured as follows. Section 2 presents the model setup and the four different intellectual property rights regimes we study. Section 3 presents the solution to the model, outlines the conditions under which each regime emerges in equilibrium, and discusses the results. Section 4 explores two extensions of the model, allowing for resale of goods and for innovation in both countries. Section 5 highlights the scope and possible limitations of the framework, in terms of the modelling choices as well as the presence of unmodelled variables which can complicate international transfer feasibility. Section 6 summarizes and concludes.

2 Model

2.1 Baseline setup

There are two countries (or regions) in the world, the industrialized North and the less developed South. Innovation consists of the development of new products. In the baseline setup, all capacity to innovate is concentrated among firms in the North (this will be relaxed in Section 4.2). Once a product has been invented, it can be produced by firms in the North and in the South at a constant marginal production cost, possibly subject to intellectual property rights such as patents. The products are consumed by households. There are n consumers in the world of which a fraction of $\gamma \in (0, 1)$ live in the North and the rest live in the South. All consumers feature identical preferences which can be represented by a linear inverse demand function.[5]

[4]There is little formal work on patent buyouts in an international setting. An exception is Scotchmer (2004), which explores theoretically how political economy considerations can affect the desirability of buyouts in an international setting, but with major differences in conceptualization and conclusions. Scotchmer (2004) assumes at the outset that buyouts are less efficient in financing innovation than patents so that global buyouts are not Pareto optimal, as well as that innovators from both the South and the North compete in making the same innovations in each country. This leads to very different results than ours: specifically, the key political economy problem is that there is *too little* patent protection in the world due to national treatment of inventors, because patent protection creates profits not just for national investors but also for foreign inventors living domestically. Therefore, the profit distribution concerns identified by the paper are very different from those we consider.

[5]The robustness of the theoretical insights to relaxing this (and other) modelling assumptions will be discussed in Section 5.

2.2 Products and innovation

The process of innovating is modelled as in Deardorff (1992). Specifically, there is a continuum of products indexed by $z \in \mathbb{R}^{\geq 0}$. To invent a product, firms must incur a research cost of $R(z) > 0$. Each product is associated with a different optimal per-capita consumer surplus; that is, the surplus per capita generated under competitive production.

Let the ratio of this surplus for product z and the product's research cost $R(z)$ be denoted by $s(z)$. That is, $s(z)$ captures the optimal per-capita consumer surplus that product z generates per unit of research cost. In choosing which products to develop, firms will thus focus on those products with the highest values of $s(z)$. Without loss of generality, let products be indexed in descending order of $s(z)$ so that the first product (indexed by $z = 0$) features the highest value of $s(z)$. The level of innovation can then be measured by a cutoff value $\hat{z}$. In particular, if the products $z \in [0, \hat{z}]$ are invented, then the total research cost incurred by firms in the North is given as

$$I(\hat{z}) = \int_0^{\hat{z}} R(z)dz. \tag{1}$$

As shown by Deardorff (1992), it is possible to express the optimal per-capita consumer surplus per unit of research cost of the *marginal* invention as a function of the total research cost I; that is, $\tilde{s}(I)$. Since we have indexed products in descending order of surplus per unit of research cost, $\tilde{s}(I)$ will be a weakly monotonically decreasing step function of I, implying diminishing marginal returns to investment in research (see Appendix A for a clarification of this method and a graphical illustration). If the number of products is large so that these steps are very small, then $\tilde{s}(I)$ can be approximated with a continuous function. Furthermore, Deardorff (1992) assumes that the speed by which diminishing returns to innovation occur is constant, so that $\tilde{s}(I)$ can be represented by a linear function of the form

$$\tilde{s}(I) = f - gI. \tag{2}$$

The intercept parameter $f > 0$ indicates how valuable inventions are in general; that is, how productive the innovation technology is.[6] The slope parameter $g > 0$ indicates the speed by which diminishing returns to innovation set in.

The level of innovation that is reached in equilibrium depends on the amount I that firms in the North invest in research, which will be endogenously determined according to the regime used to incentivize innovation (innovation regime). For any given value $I > 0$, the total consumer surplus in each country can be obtained by multiplying the expression in equation (2) with the respective number of consumers, and then integrating the resulting

[6]Formally, f is the optimal per-capita consumer surplus per unit of research cost of the highest priority invention (i.e., of the product z with the highest value of $s(z)$).

function between zero and I. For example, let $s^{o,N}$ denote the North's optimal consumer surplus (obtained under competitive pricing) per unit of research cost associated with the marginal invention. It is obtained by multiplying the per-capita consumer surplus in equation (2) by the number of consumers in the North:

$$s^{o,N}(I) = \gamma n(f - gI). \tag{3}$$

The North's total optimal consumer surplus is then given by

$$S^{o,N}(I) = \int_0^I s^{o,N}(I)dI. \tag{4}$$

Another variable of interest is profit. Let $\pi^i(I)$ denote the profit per unit of research cost that firms in the North obtain from selling the marginal invention to consumers in country $i \in \{N, S\}$. We assume the existence of competitive markets for production in the North and in the South. If there are no constraints to competitive production (i.e., in the absence of patent rights), firms will make zero profit from selling products in any country. Under monopoly production, however, profits will be strictly positive. With linear inverse demand curves, monopoly profit will constitute a fixed share of the optimal surplus obtained under competitive production, and the remaining surplus will be split equally between consumers and deadweight loss.

2.3 Innovation regimes

The level of innovation that is reached in equilibrium depends on the incentives firms in the North have to invest in research. These incentives, in turn, are determined by the innovation that is in place in the North and in the South. We will consider four types of regimes in this paper, and compare the resulting distributions of welfare across the two countries. In three of these cases, the North is the only strategic actor. In the fourth case, surplus transfers between the South and the North are possible, forming a strategic interaction space.

2.3.1 Global patent protection

The first is a regime of global patent protection where the innovating firms become monopoly producers in both countries.[7] The optimal level of research investment, I^{Patent},

[7] It does not matter for our analysis how the production is organized geographically, as long as all monopoly profits flow to the innovating firm in the North. For example, production may take place only in the North and the product is then exported to the South. Alternatively, the innovating firm may develop production capacity in the South or license out production to a producer in the South (retaining full monopoly profits).

chosen by the Northern firms in this case equates the monopoly profit from the marginal invention to its research cost. Innovation will take place up to the point where the sum of $\pi^N(I)$ and $\pi^S(I)$ (i.e., the marginal benefit of total profit per dollar of research) equals one (the marginal cost of a dollar spent on research), so that

$$\pi^N(I^{Patent}) + \pi^S(I^{Patent}) = 1. \tag{5}$$

As has been thoroughly discussed in the existing literature, the resulting value of I^{Patent} will be too small to yield the socially optimal level of innovation. The reason for this is that monopoly profits are always less than the social value of an invention. Some inventions that would be worthwhile to produce from a global welfare perspective will thus remain unexploited, because innovators are unable to extract the profits required to compensate them for the incurred research cost.[8]

2.3.2 Domestically-financed patent buyout

To overcome the inefficiencies associated with a patent system, the literature has highlighted the possibility of buyouts (also referred to as rewards or price schemes). Under a patent buyout, the government in the North purchases the patent from the innovator and places it into the public domain so that the product can be produced and sold by firms anywhere in the world. With the assumed existence of competitive markets for production, the profits of all producers will then be equal to zero.

If there is no mechanism available to transfer surplus between the South and the North, the government of the North designs and finances the buyout by itself. In this case, the amount invested in research, I^{Buyout}, is chosen so as to equate the domestic consumer surplus of the marginal invention to its research cost. The optimal level of innovation implemented by the government of the North under a domestically-financed buyout is thus determined by

$$s^{o,N}(I^{Buyout}) = 1. \tag{6}$$

Note that the South plays no role for the chosen value of I^{Buyout} because the buyout wipes out international profits, and any welfare effects on consumers in the South remain unconsidered by the North's government.[9]

[8]As described in Section 1, there are two effects through which a patent system leads to inefficiency. First, patents create monopoly distortion at the production stage which are associated with deadweight loss in consumer surplus ('static loss'). Second, and partly because of this distortion, patents never allow the innovator to extract the full social surplus of an invention. This in turn means that investment in research stays below optimum ('dynamic loss').

[9]In the concluding remarks we discuss the possibility that, in practice, rich countries may have altruistic or strategic motives to consider welfare in poorer countries.

2.3.3 Domestic subsidy

Instead of a buyout strategy the North can implement a domestic subsidy program. In this case, the government of the North offers to pay the innovators the difference between the monopoly price and the socially optimal price (i.e., the price that would prevail in a competitive market) for each unit of product sold to consumers in the North. If there is perfect information and there are no commitment problems, then the resulting quantity and consumer price in the North will be the same as under a competitive market (see also Shavell and van Ypersele, 2001). At the same time, in a multi-country world the domestic subsidy has the advantage (for the North) over a patent buyout that firms retain their patents and can sell as monopolists to the consumers abroad. The optimal level of innovation, $I^{Subsidy}$, in this case is thus determined by

$$s^{o,N}(I^{Subsidy}) + \pi^S(I^{Subsidy}) = 1. \tag{7}$$

Note that the condition in equation (7) assumes that no resale is possible internationally; that is, all subsidized production stays in the North. We discuss relaxing this assumption in Section 4.1.

2.3.4 Buyout with international transfer

Unlike the domestically-financed buyout described above, we now allow for international surplus transfers so that the governments of the North and the South can cooperate on financing a patent buyout. The model becomes strategic, involving two actors. We consider two possible scenarios as benchmarks, one where the North acts as the principal and offers a contract to the South, and one where the South is the principal and offers a contract to the North.[10] In both cases, a contract specifies the amount of a lump-sum transfer $T \in \mathbb{R}$ paid by the South to the North, and the level of innovation $I^{Transfer} > 0$ that the government of the North must implement through a buyout if the contract is accepted.[11]

The timing of the model with transfer is as follows. If the North acts as the principal, then first the government of the North offers a contract $(T, I^{Transfer})$ to the South. Second, the government of the South decides whether to accept the contract or not. If the contract is accepted, the South transfers T to the North and the North implements a buyout such that the specified level of innovation $I^{Transfer}$ is reached. If the contract is rejected, then no transfer takes place and the North is free to implement any of the other possible innovation

[10] This is equivalent to considering an agreement between the North and the South where either the North or the South holds all the bargaining power.

[11] We do not restrict T to be positive; however, it will never be optimal for the North to transfer surplus to the South in this setup.

regimes. That is, the North then either keeps global patent protection intact, implements a domestic subsidy program, or finances a patent buyout by itself (choosing freely the size of the buyout and associated level of innovation). Finally, innovation and production take place according to the prevailing property rights regime, and each country derives its welfare.

If the South acts as the principal, the offered contract is designed by the government of the South, and the North decides whether to accept or reject it. The rest of the timing is the same as above. All parties are forward looking and there is no uncertainty. In particular, when offering the contract, the South anticipates the decision of the North (and vice versa if the North offers the contract).

2.4 Objectives and welfare

The focus of our analysis is to study the international welfare implications of different innovation regimes. Specifically, we are interested in identifying the conditions under which each regime prevails in the model, and the associated distributions of welfare across the North and the South. For ease of exposition, we will start with characterizing the welfare implications of different regimes when international surplus transfers are not possible. Thereafter, we will study the North's and the South's optimal behavior across all possible regimes, including when international transfers are possible.

First, consider the tradeoff between a patent regime and a domestically-financed buyout (i.e., when domestic subsidies and international surplus transfers are not possible). The outcome in this case is determined solely by the North's optimizing behavior. If the North abstains from implementing a buyout, then its total surplus under global patent protection is given by

$$W^{N,Patent} = S^{\pi,N}(I^{Patent}) + \Pi^{N}(I^{Patent}) + \Pi^{S}(I^{Patent}) - I^{Patent}, \tag{8}$$

where S and Π denote total consumer and producer surplus in the respective country, which are found by integrating the corresponding functions of s and π until the chosen level of investment, I^{Patent}.[12] The latter is given implicitly by equation (5).

If the North implements a buyout, then consumer surplus in the North (and in the South) will be determined by competitive markets for production, eliminating any monopoly profits. The North's total surplus in this case is given by

$$W^{N,Buyout} = S^{o,N}(I^{Buyout}) - I^{Buyout}, \tag{9}$$

[12]For example, $S^{\pi,N}$ denotes the consumer surplus in the North obtained under monopoly pricing (as indicated by the superscript π).

where I^{Buyout} is determined by equation (6).[13]

Next consider the possibility of a domestic subsidy. If the North implements such a subsidy, then consumer surplus (excluding the cost of the subsidy) in the North equals the surplus obtained under competitive pricing. At the same time, firms are able to extract monopoly profits from selling to consumers in the South. The North's total surplus under a subsidy is thus given by

$$W^{N,Subsidy} = S^{o,N}(I^{Subsidy}) + \Pi^S(I^{Subsidy}) - I^{Subsidy}, \tag{10}$$

where $I^{Subsidy}$ is determined by equation (7). Note that the subsidy itself does not show up in equation (10) because it is just a redistribution between consumers and firms that is neutral to the North's total welfare.

Suppose there is no technology for international surplus transfers available. Whether the innovation regime in equilibrium involves a global patent system, a buyout, or a domestic subsidy will be determined by the North's optimizing behavior, which consists of comparing its total surplus obtained under each of the three possible regimes. Let the maximum possible welfare that the North can attain in this way be denoted by $\tilde{W}^N$, and let the associated welfare of the South in that case be denoted by $\tilde{W}^S$. One can think of these two values as representing the outside options for the North and the South when negotiating a buyout with international transfer.

If international transfers are possible, then the North's total surplus under a buyout with transfer is given by

$$W^{N,Transfer} = S^{o,N}(I^{Transfer}) + T - I^{Transfer}, \tag{11}$$

where T and $I^{Transfer}$ are specified in the contract offered by either the North or the South to the other party. If the North acts as the principal, then T and $I^{Transfer}$ are determined by the North's optimization problem:

$$\max_{T, I^{Transfer} \in \mathbb{R}} \quad W^{N,Transfer} \tag{12}$$

$$\text{s.t.} \qquad W^{S,Transfer} \geq \tilde{W}^S, \tag{13}$$

$$W^{N,Transfer} \geq \tilde{W}^N. \tag{14}$$

Condition (13) is the participation constraint of the South. Condition (14) ensures that

[13] Note that, while we will explicitly calculate the size of the buyout below, it does not show up in equation (9) because it represents a transfer between taxpayers and firms that is neutral to the country's total welfare.

the North does not fare worse under the buyout with international transfer than it would in the absence of such an agreement. The objective (12) of the North consists of choosing a contract (T,$I^{Transfer}$) so as to maximize its own welfare subject to the given constraints. If the South acts as the principal, then T and $I^{Transfer}$ are determined by an analogous optimization problem of the South which is defined in Appendix B.6.

Overall, the outcome in the model when all four considered innovation regimes are available depends on the optimizing behavior of both the North and the South. That is, either the North or the South chooses a contract specifying T and $I^{Transfer}$, and then the other country decides whether to accept the offered contract or not. If no agreement takes place, then the North chooses whether to keep the global patent system intact or to implement a domestically-financed buyout or a subsidy (as well as the respective sizes of the domestic subsidy or buyout).

3 Solution

The solution to the model consists of specifying the innovation regime, level of innovation, and associated distribution of welfare (including the size of the transfer if any) resulting under any possible combination of parameter values. The solution is formally derived in Appendix B. In essence, we first calculate the welfare obtained in the North and in the South as functions of the model's primitives for each of the four considered regimes. The resulting expressions are then used to determine the parameter value combinations under which each regime emerges as the equilibrium outcome in the model. In addition, we calculate the global welfare W^W (i.e., summing up the total welfare of each country) associated with each regime to examine whether, and to what extent, each regime creates inefficiency from a global welfare perspective. In the following subsections, we summarize the main findings in the form of propositions and discuss their underlying intuition and implications.

3.1 Propositions

Proposition 1. *For given parameter values f, g, and n, there exists a cutoff value $\overline{\gamma}_1$ of γ that determines whether the North fares better under global patent protection or under a domestically-financed buyout. If $\gamma < \overline{\gamma}_1$, then $W^{N,Buyout} < W^{N,Patent}$, and vice versa. There is a range of parameter value combinations for which $W^{N,Buyout} < W^{N,Patent}$ even though globally it holds that $W^{W,Buyout} > W^{W,Patent}$.*

Proof. See Appendix B.4. □

Proposition 1 implies that, in the absence of international surplus transfers, it can be rational for the North to abstain from implementing a patent buyout, even if such a buyout would increase global welfare relative to a patent regime. Importantly, this result holds even if there are no constraints to the implementation of an optimal buyout; that is, if the government knows the social value of each invention and there are no commitment problems nor other frictions.

This result is in stark contrast to the findings in the existing microeconomic literature on buyouts (see the studies cited in Section 1), which typically find that buyouts are always preferable to patents in a single economy setting if the government is able to pay the innovator the 'correct' amount. In contrast, the results in Proposition 1 show that once we move to a world of multiple countries, this is not necessarily the case anymore. As long as the population share of the North is not too large (i.e., $\gamma < \overline{\gamma}_1$ holds), the North fares better by keeping patent protection intact than by implementing a buyout, even if a buyout would increase global welfare relative to a patent regime.

The intuition behind this result is based on three factors in the model. First, when moving from a patent regime to a buyout the North loses the monopoly profit obtained from the Southern market. The larger the population share of the South (i.e., the smaller γ), the larger is this profit loss. Thus, smaller values of γ tend to make a buyout less attractive to the North. Second, and relatedly, the choice of regime affects firms' incentives to invest in research. As shown in the proof of Proposition 1 (in Appendix B.4), for sufficiently small values of γ it holds that $I^{Buyout} < I^{Patent}$.[14] Although this implies lower costs of innovation, it also reduces consumer surplus in the North since each additional product that is invented generates surplus. In equilibrium and for small values of γ the latter effect will dominate so that a lower level of innovation will be detrimental to the North (see also Appendix B.4). Thus, a lower value of γ also makes buyouts less attractive by reducing innovation relative to a patent regime. Third, implementing a buyout increases consumer surplus in the North by eliminating the static deadweight loss associated with monopoly pricing, but this potential gain is smaller, the smaller is the population share of the North. Therefore, in this way as well, smaller values of γ work towards making a buyout less attractive to the North.

How does the welfare of the South compare between a patent system and a buyout? If the size of the buyout is chosen and financed by the North alone (i.e., there are no international surplus transfers), then, depending on the parameter values of the model, the welfare of the South may increase or decrease as the North moves from a patent regime to a buyout. The ambiguity is due to the fact that a buyout can have two opposing effects on consumer surplus in the South. On one hand, the elimination of monopoly pricing under a buyout tends to increase consumer surplus in the South. On the other hand, a domestically-financed buyout can lead to a lower level of innovation than the one achieved under a patent system, as firms lose their ability to generate profits in the South to finance

[14] In contrast, it always holds that $I^{Buyout} > I^{Patent}$ when the North benefits from a buyout, i.e., when $\gamma > \overline{\gamma}_1$.

their research activities.[15] A lower level of innovation hurts all consumers, including those in the South.

The proof of Proposition 1 also shows that the effect of moving from patents to a domestically-financed buyout on world welfare can be positive or negative, depending on the value of γ. This implies that there can be situations where patent protection is globally preferable to a buyout even when there are no information and commitment problems. Conversely, there is a range of parameter value combinations for which a patent system decreases global welfare relative to a buyout, but the North, considering only its own welfare, chooses to maintain global patents.

The results in Proposition 1 are based on a comparison of the welfare distributions under a patent system and a buyout. In addition, however, the North might also implement a domestic subsidy program. The next proposition summarizes the results when these three regimes are compared.

Proposition 2. *It generally holds that $W^{N,Subsidy} > W^{N,Patent}$ and $W^{N,Subsidy} > W^{N,Buyout}$. A domestic subsidy also leads to higher welfare in the South than a patent regime, so that globally $W^{W,Subsidy} > W^{W,Patent}$. Whether a subsidy leads to higher global welfare than a buyout depends on the parameter values. For given parameter values f, g, and n, there exists a cutoff value $\overline{\gamma}_2$ of γ that determines whether global welfare is higher under a domestic subsidy or a buyout. If $\gamma > \overline{\gamma}_2$, then $W^{W,Subsidy} < W^{W,Buyout}$, and vice versa.*

Proof. See Appendix B.5. □

Proposition 2 implies that, in the absence of international surplus transfers, the North's dominant strategy is to implement a domestic subsidy. Relative to a patent regime, the domestic subsidy unambiguously raises welfare also in the South, and therefore globally. In contrast, whether a subsidy also leads to higher global welfare than a domestically-financed buyout depends on the relative population sizes of the two countries. For sufficiently large values of γ (i.e., $\gamma > \overline{\gamma}_2$), global welfare is higher under a buyout than under a domestic subsidy, even though the North strictly prefers the subsidy over a buyout.

The intuition behind these results is as follows. First note that a domestic subsidy allows the North to eliminate the static deadweight loss associated with monopoly pricing at home, while maintaining monopoly profits abroad. From the perspective of the North, a subsidy is thus clearly preferable to a patent system. Similarly, a subsidy is also more attractive to the North than a buyout, because a buyout achieves the same reduction in static deadweight loss at home but eliminates profits abroad.

[15] Intuitively, a buyout leads to a lower level of innovation than a patent system if γ is sufficiently small (i.e., the population of the North is small compared to the South) for given other parameter values (see Appendix B.2).

In addition to reducing static deadweight loss while preserving profits abroad, a subsidy also increases welfare of the North by generating a higher level of innovation than achieved under a buyout or a patent system. In particular, it generally holds in the model that $I^{Subsidy} > I^{Buyout}$ and $I^{Subsidy} > I^{Patent}$ (see Appendix B.3). This increase in innovation benefits the North in two ways. First, it increases consumer surplus because each additional product that is invented generates surplus. Second, the new products generate additional monopoly profits from the Southern market which flow to the innovating firms in the North.

For the South, it can be shown (see the proof of Proposition 2) that welfare is strictly greater under a subsidy in the North than under a global patent system. Intuitively, this follows from the fact that the South is subject to static losses due to monopoly pricing both under a patent regime and under a subsidy in the North, while dynamic losses are smaller under a subsidy program due to the higher level of innovation.

Whether a subsidy program leads to higher or lower welfare in the South, and globally, compared to a buyout depends on the relative population sizes of the two countries. As long as the population share of the North is not too small (i.e., $\gamma > \overline{\gamma}_2$ holds), the South will fare better under a buyout than under the subsidy. The intuition behind this result is as follows. The larger the population share of the North, the smaller is the reduction in the level of innovation when moving from a subsidy to a buyout. This is due to the fact that the role that profits from the South play in financing innovation under a subsidy is smaller if the South's population share is smaller. This attenuates the negative effect on the South's welfare stemming from the reduction in innovation when moving from a subsidy to a buyout, relative to the positive effect associated with eliminating monopoly pricing. Specifically, if $\gamma > \overline{\gamma}_2$, then the South gains from a buyout relative to domestic subsidy and this gain exceeds the losses to the North. In this case, global welfare is higher under a buyout than under a domestic subsidy in the North, making the North's dominant strategy of domestic subsidies harmful to global welfare.

The next proposition clarifies how this result changes when international surplus transfers are feasible.

Proposition 3. *If international surplus transfers are possible, then the equilibrium outcome will be Pareto optimal and involve a buyout with $T > 0$ that stipulates the globally efficient level of innovation. The exact size of T and resulting distribution of welfare depend on the relative bargaining power of the two countries.*

Proof. See Appendix B.6. □

Comparing the results in Proposition 2 and Proposition 3 shows that the presence of a technology for international surplus transfer is both necessary and sufficient for achieving a Pareto optimal outcome in the model. Without international transfers, the North's dominant strategy of domestic subsidies leads to an inefficiently low level of innovation, where some products that would be worthwhile to invent from a global welfare perspective remain unexploited. If international surplus transfers are possible, then it is in the best interest of both countries to cooperate on financing a buyout which ensures that the globally efficient level of innovation is reached; that is, all products z are invented for which the total optimal consumer surplus (achieved under competitive pricing) in both countries is greater than the research cost. Both the North and South would benefit from such a move relative to their position under the subsidy status quo.

Whereas the size of the transfer and the resulting distribution of welfare gains depend on the relative bargaining power of each country, the size of the buyout and associated level of innovation are independent of the distribution of bargaining power (in line with the Theorem of Coase, 1960).[16] Importantly, the result that both countries will find it optimal to agree on a buyout if international transfers are possible is independent of the parameter values of the model, and thus does not depend on the relative population sizes of the North and the South.

3.2 Discussion

The related theoretical literature on patent buyouts largely considers the merits of patents versus buyouts from the perspective of a single economy. Our model complements these insights by showing that the optimal choice also depends on the effect of these innovation regimes on international profit redistribution. This applies even in the absence of the information and commitment problems considered in the previous literature.

The crux of the challenge identified in our model is that while patents are in effect financed by all consumers worldwide who purchase the resulting products, the cost of buyouts would, in the absence of feasible international transfers, be borne solely by the innovating country. Therefore, the conflict of interest between countries of different innovation and financing capabilities emerges particularly sharply in the public financing arrangement (buyouts), and the essential trade-off facing the North is between reducing deadweight loss from patents and losing international profit from buyouts. Facing a choice only between global patents and global buyouts, the innovating country's government will still choose to finance a buyout if the costs of free riding are lower than the domestic costs of monopoly pricing, and it will keep patents globally if the converse condition applies, irrespective of how this impacts world welfare.

The model also emphasizes that arrangements which weaken this trade-off for the North would render buyouts a moot point. In particular, what we call domestic subsidy pricing can stem the harmful effects of patents to Northern consumers while maintaining profits

[16]Intuitively, the welfare of each country is higher if it has more bargaining power, and the amount transferred from the South to the North is smaller if the South has more bargaining power (see Appendix B.6).

from captive international markets. In light of this, a mixed-incentives approach in which the cost of patented products is subsidized in advanced countries, for example through health insurance for drugs, while allowing innovating firms to retain the underlying patents, emerges as a domestically desirable choice and does not need to be explained by the problems highlighted in the previous literature. Once again, as long as the decision to maintain or remove patents is undertaken by the government of the innovating country, the welfare of the rest of the world will be an afterthought. As Proposition 2 shows, this choice is more likely to be detrimental to world welfare the smaller the South's purchasing power is. The North would only lose a small amount, and the world benefit significantly, from a move to a buyout regime, but, as the only strategic player, the North will have no incentive to incur even this small extra cost and to reverse its dominant strategy.

The international setting therefore complicates the choice of innovation regime and the subsequent welfare implications. Only in the presence of intersovereign transfers do these issues disappear, as transfers override the coordination problems at the international level and generate what resembles a single-economy market. Only in this case, therefore, we obtain conclusions mirroring those of a single economy: that without information and commitment problems, the achieved innovation regime in equilibrium is a buyout which generates the Pareto optimal level of innovation. However, as we discuss in Subsection 5.2, such transfers are likely to be impeded in practice by a number of factors. This can help to explain why, in addition to the information and commitment problems discussed in the literature, regimes that maintain patents in full or in part remain the predominant method of incentivizing innovation, even when buyouts can improve global welfare.

4 Extensions

We now explore two extensions of the baseline model discussed above. First, we study how the possibility of (unlicensed) resale of goods in the case of a domestic subsidy in the North affects the modelling insights. Second, we consider what happens when both countries can innovate in different sectors.

4.1 Resale

So far, the domestic subsidy case has abstracted from the possibility of resale; that is, that products may be bought at subsidized prices in the North and then sold to consumers in the South. In relaxing this assumption, we allow for different degrees of resale. This is captured by the variable $r \in [0, 1]$ which specifies the share of the North's monopoly profits in the Southern market that are lost due to resale. The North's surplus under a domestic subsidy with resale is then given by

$$W^{N,Resale} = S^{o,N}(I^{Resale}) + (1 - r)\Pi^S(I^{Resale}) - I^{Resale}. \tag{15}$$

The value $r = 0$ corresponds to zero resale (i.e., the baseline model described in Section 2). If $r = 1$, there are no constraints to resale so that the price consumers pay in the South equals the competitive (subsidized) price in the North and foreign profits to the North are fully eliminated. For values $r \in (0, 1)$, resale is partially possible. For example, one may think of this case as capturing constraints to resale, such as legal constraints or costs due to tariffs, which prevent perfect resale.

The presence of resale affects the implications of the model in several ways. The main results are summarized in the next proposition.

Proposition 4. *If $r \in (0, 1)$, then $I^{Resale} < I^{Subsidy}$ and a domestic subsidy is not necessarily the dominant strategy of the North in the absence of international transfers. While it generally holds that $W^{N,Resale} > W^{N,Buyout}$, whether $W^{N,Resale}$ is larger than $W^{N,Patent}$ depends on the parameter values. For given values f, g, n, and r, smaller values of γ make a patent more attractive to the North than a subsidy under resale.*

The presence of resale leaves intact the insight that international surplus transfers can generate a Pareto optimal equilibrium outcome with the globally efficient level of innovation. However, the size of the transfer and the associated distribution of welfare will be different under resale and dependent on the value of r.

Proof. See Appendix B.7. □

Under a domestic subsidy program, the presence of resale reduces the level of innovation and the welfare of the North. The latter effect happens both along the intensive and extensive margin. There is a cut on the profits at any given level of innovation (the intensive margin) as some consumers in the South are able to purchase goods at prices below the monopoly prices. In addition, there are less products available to make profits (the extensive margin) since resale leads to a lower level of innovation.

Proposition 4 states that, as long as resale is only partial (i.e., $r \in (0, 1)$), the North still strictly prefers a domestic subsidy over a domestically-financed buyout (as in Proposition 2).[17] However, for certain parameter value combinations, resale causes a domestic subsidy to be less attractive to the North than global patent protection. Hence, the presence of resale can alter the result from Proposition 2 that a subsidy is always the North's dominant strategy in the absence of international transfers.

At the same time, the presence of resale leaves intact the result from Proposition 3 that, if international surplus transfers are possible, the equilibrium outcome consists of a buyout which stipulates the globally efficient level of innovation. In this case, merely the size of the transfer and the associated distribution of welfare are affected by resale, as the

[17] Under perfect resale (i.e., $r = 1$), the North is indifferent between a subsidy and a domestically-financed buyout (see Appendix B.7).

threat point of the North (i.e., to implement a domestic subsidy instead of a buyout) is weakened when resale is possible.

4.2 Two innovating countries

In the baseline model all capacity to innovate is concentrated among firms in the North. We now extend the model to allow for innovation capacity in the South and show that, as long as the countries innovate in different sectors, the model's main implications remain intact.

Suppose firms in both the North and South can innovate but in different (non-overlapping) sectors. For example, this may reflect that the two countries are structurally different, perhaps along the development gradient (e.g., one country innovates in a capital-intensive sector while the other innovates in a labor-intensive sector). Production and pricing of the subsequent goods are a function of the innovation regime chosen by the innovating firms' government. Each country's welfare is a function of innovation in both sectors and therefore of innovation policies in both countries. More precisely, we now assume that the world population derives welfare from two different optimal consumer surplus curves (two curves each similar in structure to Figure A1), and that welfare is additively separable in each sector. The parameters f and g are allowed to differ across sectors.

Within each country, the government has the same set of options regarding the spectrum of domestically-produced inventions as in the baseline model: to implement a global patent regime, a price subsidy regime, or a patent buyout. The model's equilibrium in this case can be obtained as the result of a simple 3-by-3 simultaneous game with the strategy space $\{Patent, Subsidy, Buyout\}$ for each player.

For each country, instituting a patent regime or a subsidy involves the optimality conditions paralleling equations (5) and (7), respectively. In addition, we consider two possible strategies regarding buyouts. First, country $i \in \{N, S\}$ may finance innovation in its sector through a buyout by considering only its own welfare, same as in equation (6):

$$s^{o,i}(I^{Buyout}) = 1. \tag{16}$$

Alternatively, buyouts may involve a cooperative strategy (e.g., based on reciprocity) in which each country acts as a global welfare maximizer in its sector. This possibility emerges in a game precisely because there may be benefits to such other-regarding preferences, through reciprocity. For both countries, the optimality condition in what we call the 'cooperative buyout' is given by

$$s^{o,N}(I^{Buyout}) + s^{o,S}(I^{Buyout}) = 1. \tag{17}$$

The following proposition summarizes the results.

Proposition 5. *With both countries innovating in non-overlapping sectors, each country will pick price subsidies for its sector as a dominant strategy, resulting in a* $\{Subsidy, Subsidy\}$ *equilibrium. For buyouts that focus on maximizing domestic welfare only, world welfare under* $\{Buyout, Buyout\}$ *may be smaller or larger than that of* $\{Subsidy, Subsidy\}$*, depending on the parameters of the model. For cooperative buyouts, there exist parameter value combinations for which both countries are worse off in the subsidy equilibrium than in a mutual buyout, resulting in a Prisoner's Dilemma. In both cases, only feasible and credible transfers outside the game can move the world to the globally optimal buyout regime.*

Proof. See Appendix B.8. □

Even when innovation capacity is spread across countries, then so long as it is concentrated in different sectors, price subsidies will remain a dominant strategy. The logic is that each country calculates that it will be better off if it subsidizes its own sector regardless of what the other country chooses to do, thereby making buyouts a non-credible strategy (one on which each player has an incentive to renege).

Moreover, Proposition 5 implies that subsidies in both sectors hold as the unique equilibrium regardless of how mutual buyouts would compare in terms of world welfare. In fact, when the buyout strategy is cooperative (reciprocal), then a mutual buyout would not only optimize world welfare but also make each country better off than it would be under the subsidy equilibrium. The result is a Prisoner's Dilemma structure, with both countries stuck in the Pareto inferior equilibrium.[18] As with the one-country case, transfers (outside the game) which compensate each country for the externality generated by its sector would motivate buyouts. However, the credibility of these transfers would rely on enforceable and binding supra-national contracts (as discussed in more detail in Section 5.2).

5 Scope and limitations

This section focuses on some of the explicit modelling choices and discusses how these might affect our results. The discussion is framed in terms of the baseline model (from Section 2) but similar conclusions can be drawn about the extended model in the features it shares with the baseline model. Thereafter, we discuss a number of features that are absent from the model which may affect the feasibility of buyouts financed by international transfers.

[18] The Prisoner's Dilemma can also arise for finitely repeated dynamic games, or for infinite horizon dynamic games with sufficiently low discount factors.

5.1 Modelling choices

Identical linear demand functions. The model assumes that consumers in both countries feature the same inverse demand functions for all goods, and that these functions take a linear form. Linearity of demand ensures the existence of a closed-form solution and helps to keep the model tractable. However, it is not a critical feature for our results. What is needed is that monopoly pricing leads to a strictly positive loss in welfare, but this would also hold under many other types of demand functions (see also the corresponding discussion in Deardorff, 1992).

With respect to the assumption of identical consumers, if the quantity of some invented product demanded per consumer was different in the North and the South, then the magnitude of the tradeoffs faced by the North would change. In the extreme case, this would affect the results in Proposition 1. To see this, consider the two extreme cases of an innovation set A that generates products only demanded by consumers in the North, and an innovation set B that generates products only demanded in the South. In the case of B, moving from a patent system to a buyout without transfers would eliminate any research investment for this invention, as the North would not enjoy any of the surplus associated with B. In this case, and deviating from the results in Proposition 1, welfare of the South (and globally) would always be greater under a patent regime than under a buyout, and there would be no value of γ for which the North would implement a buyout. Similarly, for A the North would always implement a buyout (irrespective of the value of γ). At the same time, the key results in Proposition 3 would remain intact, as a Pareto-improving buyout with international transfer could be implemented both for A and for B (for A, the transfer would equal zero).

Linear surplus function of innovation. Our model follows the assumption made by Deardorff (1992) that the surplus function $\tilde{s}(I)$ of innovation is linear, implying that the speed by which diminishing returns to innovation occur is constant. Relaxing this feature will affect the trade-offs facing the North when choosing between different innovation regimes, so that the quantitative results (e.g., the derived expressions of the cutoff values $\overline{\gamma}_1$ and $\overline{\gamma}_2$) will be sensitive to changes in the functional form of $\tilde{s}(I)$. Focusing on the policy implications of the model, this also means that the ability to form cases for or against certain innovation regimes will vary across different functional forms. However, as long as $\tilde{s}(I)$ is a continuous decreasing function, the qualitative predictions of the model will remain largely the same. For example, the result that the North's dominant strategy in the absence of international surplus transfers involves a domestic subsidy (Proposition 2) will also hold if $\tilde{s}(I)$ is continuous, decreasing, and either concave or convex. The same applies to the result on the optimality of internationally-financed buyouts in Proposition

3.[19]

Symmetric production costs. The model assumes that a patent buyout leads to the same competitive pricing of invented products in the North and in the South. This implies that the geographical organization of production is irrelevant; that is, it does not matter whether all production capacity is concentrated in the North and products are exported to the South, or the South also features some production capacity.[20] The model is therefore unable to capture important considerations in the context of industrial development and employment.

At the same time, relaxing the assumed symmetry in production would mostly affect our results quantitatively while keeping most of the key qualitative insights intact. For example, suppose that consumers in the South would face higher prices under a buyout than consumers in the North because the marginal cost of production is higher in the South than in the North (e.g., due to less productive technology and infrastructure) or because markets for production are not fully competitive in the South, and shipping products from the North to the South is subject to transportation costs. The existence of such price differences will tend to reduce the benefits of a buyout to the South and thus affect the results of the model quantitatively (e.g., the derived cutoff values in Propositions 1 and 2 would change). However, the qualitative insights obtained from Propositions 1 to 3 would largely remain the same. For example, the North would still prefer a system with domestic subsidies over a nationally-financed buyout (Proposition 2), and the globally efficient level of innovation is only reached in the presence of international transfers (Proposition 3).

Market frictions. In the model, innovations are readily purchased and consumed by n individuals distributed with share γ in the North, if their associated utility exceeds the cost. This abstracts from the fact that consumers may face binding constraints in financing the consumption of new products, and that these constraints may systematically differ across countries. If there are individuals who are constrained from paying the equivalent of their marginal benefit from an innovation (e.g., due to frictions in the credit market) but these constraints are not considered in the model, then our model will tend to overestimate the value of innovation. To the extent that such constraints are concentrated in the South, this would also reduce the benefits of a buyout to the South (and globally) relative to what our model suggests.[21]

[19] In addition, we might echo here Deardorff's argument that, in the absence of any information about the true functional form of $\tilde{s}(I)$, assuming linearity appears to be the most appropriate choice.

[20] This applies if producers make zero profits under a buyout (i.e., when production takes place in a competitive environment) and if all profits generated under a patent system flow to the North (e.g., through licensing; see also footnote 7).

[21] To see this, consider a household in the South with a valuation of an innovation below the monopoly price but above the competitive price. When moving from a system of global patent protection to a buyout, the model assumes that the household will purchase the innovation, contributing to a rise in the South's consumer surplus. However, if market frictions such as credit constraints prevent the household from purchasing the product, then the increase in consumer surplus associated with a buyout will be lower

In addition to constraints on the ability to pay, institutional constraints in the South may have a similar effect. For example, many health-based innovations are delivered through the health system. If these institutions in the South are limited in their ability to procure such products (even in the absence of financial constraints) due to organizational problems, or to administer them due to human capital issues, then the effective demand in the South will be smaller than assumed by our model. For example, Marcus et al. (2022) find persistently low use of statins, which protect against cardiovascular disease, in low and middle-income countries even after prices for these drugs fell after patent expiry, due to poor diagnostics and lack of sufficient integration of statins into the primary health care systems of these countries. More generally, organizational problems in the healthcare institutions of developing countries can be severe even when financial constraints are not (Ahmad, 2021).

Static framework and partial equilibrium. Our theoretical insights are based on a static model which abstracts from dynamics over time. Of course, this does not mean that the model is unable to capture both the static and the dynamic losses associated with patents, as the latter are reflected in the size of I. However, the static nature of the model prevents us from studying some of the aspects that have been the focus of previous work in the literature, such as the roles of patent length and the timing of buyouts (i.e., the possibility for governments to pursue a mixed strategy where innovators are allowed to enjoy monopoly power for a certain period of time until the government decides to implement a buyout, possibly depending on uncertain market conditions).

In addition, our model takes the volume and distribution of demand (captured by the parameters n and γ), the contribution of innovation to social surplus (captured by f and g), and the cost of innovation (R) as determined exogenously to the model and fixed with respect to the innovation regime in place. While this is in line with the approach taken by many other studies in the literature on patent protection and buyouts (e.g., most of the studies cited in Section 1), it is important to note that such an approach abstracts from general equilibrium effects that might determine those variables. For example, one may be concerned that innovation regimes which increase total investment into research also reduce the research cost for subsequent innovations. Similarly, an innovation regime which lowers prices may (over time) affect the structure of demand, possibly differently in different countries. Modelling such processes would require a richer model in which demand and innovation regime are jointly determined, which is left for future research.

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than implied by the model.

5.2 Why are transfers so rare in practice?

The model generates the strong implication that buyouts financed internationally by transfers allow for outcomes that not only maximize global welfare but also constitute Pareto improvements to regimes based on global patent protection. In light of these results, it seems puzzling that transfers are relatively rarely observed in practice.[22] In this section, we discuss several factors which may explain why transfer-financed buyouts (focusing on transfers from the South to the North, as in the baseline model) are not the predominant mode of incentivizing innovation.

Limited ability to tax. First, like most models studying buyouts, our model implicitly assumes that governments can extract any share of their consumers' surplus using non-distortionary taxes. The ability of governments to tax is crucial for the feasibility of an international buyout solution, because the North will only commit to a buyout if the government of the South is able to finance the transfer. Thus, if the capacity to tax is severely limited in less-developed economies (i.e., in countries with little innovation capacity), then this may explain why international buyouts do not take place more often. There are often severe challenges toward the mobilization of domestic resources in developing countries including weak institutions and low taxation paying norms (Besley and Persson, 2014). At a more fundamental level, low taxation rates in developing countries may be due to the particular challenges of governance and rent distribution in a setting when the budget is limited and when the economy is largely unproductive, rendering informal and personalized transfers a more feasible method of distributing entitlements to politically powerful social groups (Khan, 2012). In this case, broad-based economic development and a move to a more productive economy is a necessary condition for improving taxation capabilities.

Commitment problems. Second, even if the government in the South can collect sufficient taxation for the purposes of a transfer, such a transfer must be credible from the perspective of the North if the latter expects to be reimbursed after the fact.[23] Possible commitment problems may mirror those in Galasso (2020), where a government that commits to a buyout transfer to the firms in its country can face unexpected shocks that require diversion of resources after the commitment has been made, undermining the credibility of its promise. Galasso shows that credibility will be undermined under specific conditions but the general necessary condition is that the budget is too small to accommodate both the promised transfers and the unexpected shock. Applied to a situation where the transfer is between a South and North government, the precipitating conditions for a commitment

[22] While it is possible that the benefits of a buyout to the South are lower when there are frictions that reduce the ability of consumers to make use of the innovated products (see the discussion in Subsection 5.1), this does not eliminate the fact that transfers for a globally financed buyout remain Pareto optimal.

[23] Of course, if the transfer must occur prior to the buyout, then the problems described in this paragraph remain a major obstacle to feasibility albeit not in the framework of ex-post credibility.

problem are even more plausible. Governments in resource-constrained economies are more likely to have limited budgets, while general political and economic fragility (as well as potentially corruption) will exacerbate the extent to which shocks occur and demand the diversion of previously promised resources.[24] In the absence of a supra-sovereign enforcer of agreements between sovereigns, it is difficult to see how such commitment problems, if they exist, can be overcome.

Imperfect information. Third, our model abstracts from information constraints and assumes that governments know the social value of innovations. Abstracting from imperfect information in the model is necessary to ensure that a buyout eliminates the static deadweight loss associated with the monopoly pricing under a patent system. If governments are unable to derive the social value of innovations, then a suboptimal buyout amount that is too high or too low may not necessarily lead to a better outcome than a patent system. In this case, it would not be surprising that buyouts are rarely observed in practice even if international coordination and ability to finance transfers were not binding constraints.

The role of imperfect information in determining the optimality of buyouts relative to patents has been thoroughly discussed in the existing literature that studies buyouts in single-economy settings (Wright, 1983; Scotchmer, 1999; Shavell and van Ypersele, 2001). Most of the insights from these models also apply to the two-country case, so that there is not much to add to the existing literature in this regards. However, there is a small refinement generated by the two-country model that should be noted here. Several previous studies highlight that it is not necessary for the government to know the exact value of an innovation *ex ante* (i.e., at the time the innovation is registered) in order to implement an adequate buyout. Rather, the government can make use of different mechanisms to elicit the relevant information, for example through auctions (Kremer, 1998) or based on market signals generated after a new product has hit the market (Chari et al., 2012; Galasso et al., 2016). In a single-economy model, it seems relatively harmless to assume that the government can observe market signals such as sales and prices (Shavell and van Ypersele, 2001). However, once we move to a two-country world, the government of the North would also need to be able to observe such signals for foreign markets in order to choose the optimal buyout amount.[25] If, in practice, obtaining such information from abroad involves costs or other frictions, then a buyout agreement will tend to be less attractive than implied by the model.

[24]Note that this can occur *in addition to* commitment problems domestically in the North between the government and the innovating firms (i.e., those studied by Galasso (2020)).

[25]This will be particularly important if (unlike in our model) consumers' demand functions differ across countries.

6 Conclusion

Innovators must be compensated for investing in innovation, but it has long been understood that doing so by granting innovators monopoly profits is distortionary and inefficient (Wright, 1983). By contrast, a buyout in which the government directly transfers the requisite surplus to the innovator could in principle circumscribe the need for monopoly power. The literature on buyouts, focused on single-country models, has shown that if the government can calculate and commit to transferring the social surplus to the innovator, then buyouts are clearly welfare enhancing.

In this paper, we depart from the focus on single economies and explore the incentives for and implications of buyouts in a world with two heterogeneous countries featuring different sizes and capacities to innovate. The model shows that the optimal choice between a patent and a buyout regime depends critically on the effect on international profits, a consideration which is absent in single-economy models. The key tradeoff from the perspective of the innovating country is that buyouts, even when perfectly calculated and feasibly committed to, not only remove the distortionary effects of monopoly domestically but also result in a loss of profits internationally from previously captured foreign markets. Consequently, we also show that arrangements which weaken this tradeoff for the North, such as domestic subsidy pricing that diminishes the harmful effects of patents to Northern consumers while maintaining patent-based profit from international market, are an attractive alternative (as long as they can be implemented; i.e., if resale is sufficiently limited). Moreover, the model suggests that when both countries innovate and choose innovation regimes (in different sectors), then the countries may be stuck in a Prisoner's Dilemma where they remain at the Pareto inferior equilibrium of mutual subsidies even as mutual buyouts would make them both better off. Finally, we demonstrate that if international collaboration (e.g., based on surplus transfers or reciprocity) is feasible, then this will result in a Pareto-optimizing equilibrium with global buyouts. This is because intersovereign transfers (or reciprocity, if possible) eliminate the crux of the political economy challenge of a buyout, which is that while the cost of patents is borne by consumers everywhere, the cost of the buyout would (in the absence of transfers) be borne solely by the innovating country.

Our results demonstrate that the institutionalization of buyouts as an alternative to patents depends on considerations around the subsequent distribution of welfare gains globally. More specifically, whereas patents, at least in theory, extract profit from all consumers regardless of their origins, the domestic welfare gains from buyouts depend on which government is financing them. In the absence of feasible and credible mechanisms for intersovereign transfers, the global benefits from a buyout would not align with domestic benefits for the innovating country, with the latter instead instituting, where possible, a mixed-incentive regime that reduces domestic deadweight loss from patents while preserving patent profits internationally. In this case, the globally Pareto optimal regime of a buyout exemplifies an under-provisioned global public good, with potentially large welfare losses for the non-innovating region.

One implication of the modelling insights is that international collaboration on patent buyouts is both necessary and sufficient to achieve a globally efficient level of innovation. The model thus provides a strong case for efforts aimed at developing mechanisms that facilitate such collaboration, which feature into the agenda of recent initiatives such as the Health Impact Fund (Banerjee et al., 2010) and Advanced Market Commitment (Kremer et al., 2020, 2022).

In addition, the model suggests that patent buyouts may be viewed as an alternative channel for foreign aid, with possible benefits compared to other forms of aid. For example, many life-saving drugs can be produced at very low cost but monopoly pricing under patent protection prevents consumers in low-income countries from being able to afford these drugs (Stiglitz and Jayadev, 2010; Cockburn et al., 2016). If rich countries financed a buyout for these drugs that would hold the level of innovation fixed, then this would clearly increase consumer surplus in the world. Of course, the model also shows that such a buyout may not be aligned with the self-interest of the rich countries, due to the lost profits abroad. In this case, an altruistic donor may help bridge the gap in order to expand global access to the patented drugs. In addition, if there are other reasons why rich countries want to make transfers to poorer economies, then patent buyouts might provide an alternative channel with possible benefits compared to other forms of aid, such as lower scope for elite capture.[26]

Of course, the global redistributive consequences of patented technologies and the potential toll on populations in the global South, as well as the question of alternative systems of incentivizing innovation, have taken on renewed importance and urgency in light of the COVID-19 pandemic. In fact, resistance by innovating countries to the placement of vaccine innovations in the public domain has often been framed in terms of concerns about international profit losses for innovating countries. Although our paper is a general theoretical exploration which does not engage with the specifics of vaccine innovation and production nor with the welfare ramifications of contagious disease, we believe the framework presented here can help shed light on the primacy of such political economy concerns in the choice (and consequences) of patent regimes versus other innovation regimes more generally.

[26] For example, rich countries may have international development goals, or they may want to limit migration pressures or contain the international spread of contagious diseases.

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APPENDIX

A Optimal consumer surplus as a function of the total research cost

Suppose per-capita demand for a single product z_i can be approximated by a linear inverse demand function

$$p_i = a_i - \frac{b_i}{n} q_i, \tag{A.1}$$

where p_i is the price, q_i is total market demand, n is the number of identical consumers, and a_i and b_i are parameters. Assuming constant marginal production costs c_i for each product, then equating price to marginal cost yields the optimal demand per capita

$$\frac{q_i^*}{n} = \frac{(a_i - c_i)}{b_i}. \tag{A.2}$$

If the product is sold at marginal cost, then its optimal per-capita consumer surplus is given by

$$\frac{S_i^o}{n} = \frac{\int_0^{q_i^*} (p_i - c_i)dq}{n} = \frac{(a_i - c_i)^2}{2b_i}. \tag{A.3}$$

Let the cost of *research* that went into inventing z_i be denoted by $R(z_i)$. Dividing the optimal per-capita consumer surplus by the research cost yields

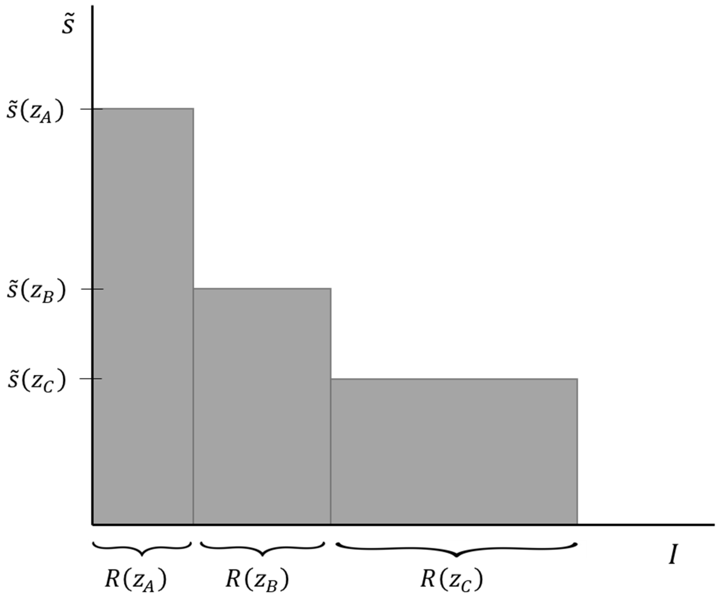
$$\tilde{s}(z_i) \equiv \frac{S_i^o}{nR(z_i)} = \frac{(a_i - c_i)^2}{2b_i R(z_i)}. \tag{A.4}$$

Ordering inventions in descending order of $\tilde{s}$ allows for $\tilde{s}$ to be expressed as a monotonically decreasing function of I, where $I = \int R(z)dz$ is the total research cost for all invented products. To see this, consider the following example with three products:

- z_A generates $S_A^o/n = 20$ and $R = 2$ is incurred in its invention.
- z_B generates $S_B^o/n = 15$ and $R = 3$ is incurred in its invention.
- z_C generates $S_C^o/n = 18$ and $R = 6$ is incurred in its invention.

The respective optimal per-capita consumer surplus per dollar of research cost ($\tilde{s}$) for these products is 10, 5, and 3. Descending order of $\tilde{s}$ therefore implies z_A, z_B, z_C. Plotting the relevant descending order of $\tilde{s}$ over I yields the graph in Figure A1.

Figure A1: Optimal consumer surplus $\tilde{s}$ as a function of total research cost I



Source: Authors' illustration.

Due to the ordering, $\tilde{s}$ is a weakly decreasing step function of I. Moreover, it can be seen that the combined area shaded is equal to $20+15+18$, which is the sum of per-capita optimal consumer surplus across all products. When there are many inventions, this can be calculated by taking the integral of $\tilde{s}$ up until I:

$$\frac{S^o}{n} = \sum_i \frac{S_i^o}{n} = \int_0^I \tilde{s}(I)dI. \tag{A.5}$$

Multiplying this equation through by n provides the total optimal consumer surplus across all products:

$$S^o(I) = \int_0^I n\tilde{s}(I)dI. \tag{A.6}$$

B Proofs of propositions

This appendix derives the solution to the model along the following steps. First, we calculate the optimal behavior and associated welfare of the North and the South as functions of the model's primitives separately for each innovation regime. We then compare the resulting expressions with each other to determine the regime that emerges in equilibrium for any given parameter value combination. The proof of Proposition 1 is obtained in Appendix B.4 by comparing the outcomes under global patent protection and a domestically-financed buyout. The proof of Proposition 2 is obtained in Appendix B.5 by considering the additional possibility of a domestic subsidy program in the North. Finally, the proof of Proposition 3 is obtained in Appendix B.6 by deriving the solution across all possible regimes when international surplus transfers are possible.

B.1 Global patent protection

Under a regime of global patent protection, the optimal level of research investment, I^{Patent}, chosen by the firms in the North is determined by equation (5). With the made assumptions that demand is linear and the marginal cost of production is constant, it is well known that the monopoly profit amounts to exactly one half of the optimal consumer surplus (obtained under competitive pricing) in a given country. The same holds for the surplus associated with the marginal invention expressed per unit of research cost (see Deardorff, 1992), so that

$$\pi^i(I) = \frac{1}{2}s^{o,i}(I), \ i \in \{N, S\}. \tag{B.1}$$

The remaining surplus is split equally between consumers and deadweight loss, so that the consumer surplus per unit of research cost under monopoly pricing and linear demand can be expressed as a fixed share of the optimal surplus:

$$s^{\pi,i}(I) = \frac{1}{4}s^{o,i}(I), \ i \in \{N, S\}. \tag{B.2}$$

Using the expression of $s^{o,N}$ from equation (3) and noting that $s^{o,S}(I)$ is given by an analogous expression with $(1-\gamma)$ instead of γ, the optimality condition (5) can be written as

$$\frac{1}{2}\gamma n(f - gI) + \frac{1}{2}(1-\gamma)n(f - gI) = 1. \tag{B.3}$$

Solving for I shows that the optimal level of research investment under a global patent regime is given by

$$I^{Patent} = \frac{nf-2}{ng}. \tag{B.4}$$

The associated welfare of the North is given by equation (8). The North's total consumer surplus under monopoly pricing, $S^{\pi,N}(I)$, can be calculated by integrating $s^{\pi,N}(I)$ (expressed per unit of research cost) from equation (B.2) up to the level of research I^{Patent}. In the same way, the monopoly profit, $\Pi^i(I)$, in each country can be calculated by integrating $\pi^i(I)$ from equation (B.1) up to I^{Patent}. Plugging the corresponding terms into equation (8) and simplifying the resulting expression leads to

$$\begin{aligned} W^{N,Patent} &= \int_0^{I^{Patent}} s^{\pi,N}(I)dI + \int_0^{I^{Patent}} \pi^N(I)dI + \int_0^{I^{Patent}} \pi^S(I)dI - I^{Patent} \\ &= \int \frac{1}{4}\gamma n(f-gI)dI + \int \frac{1}{2}\gamma n(f-gI)dI + \int \frac{1}{2}(1-\gamma)n(f-gI)dI - \frac{nf-2}{ng} \\ &= \frac{nf-2}{8ng}\Big[(2+\gamma)(nf+2) - 8\Big]. \end{aligned} \tag{B.5}$$

The welfare of the South under a global patent regime consists of the consumer surplus obtained under monopoly pricing. This can be calculated as

$$\begin{aligned} W^{S,Patent} &= \int_0^{I^{Patent}} s^{\pi,S}(I)dI \\ &= \int \frac{1}{4}(1-\gamma)n(f-gI)dI \\ &= \frac{(1-\gamma)(n^2f^2-4)}{8ng} \end{aligned} \tag{B.6}$$

B.2 Domestically-financed patent buyout

If the government of the North implements a buyout without receiving any surplus transfer from the South, then the optimal level of innovation is determined by equation (6). Plugging in the expression of $s^{o,N}$ from equation (3) and solving equation (6) for I shows that the optimal level of research investment under a domestically-financed buyout is given by

$$I^{Buyout} = \frac{\gamma nf - 1}{\gamma ng}. \tag{B.7}$$

Notice that $I^{Buyout} > I^{Patent}$ whenever $\gamma > 0.5$; that is, whenever the population (market) size of the North is larger than that of the South.

Using the derived expression of I^{Buyout}, the welfare of the North under a buyout can be calculated from equation (9) as

$$\begin{aligned} W^{N,Buyout} &= \int_0^{I^{Buyout}} s^{o,N}(I)dI - I^{Buyout} \\ &= \int \gamma n(f-gI)dI - \frac{\gamma nf - 1}{\gamma ng} \\ &= \frac{(\gamma nf-1)^2}{2\gamma ng}. \end{aligned} \tag{B.8}$$

The associated welfare of the South can be calculated as

$$\begin{aligned} W^{S,Buyout} &= \int_0^{I^{Buyout}} s^{o,S}(I)dI \\ &= \int (1-\gamma)n(f-gI)dI \\ &= \frac{(1-\gamma)(\gamma^2n^2f^2-1)}{2\gamma^2 ng}. \end{aligned} \tag{B.9}$$

B.3 Domestic subsidy

If the government of the North implements a domestic subsidy, then the optimal level of innovation is determined by equation (7). Plugging in the corresponding expressions of

$s^{o,N}$ and π^S from equations (3) and (B.1), and solving for I, shows that the optimal level of research investment under a subsidy in the North is given by

$$I^{Subsidy} = \frac{nf(1+\gamma)-2}{ng(1+\gamma)}. \tag{B.10}$$

Notice that for all feasible parameter values of $\gamma \in (0,1)$ it holds that $I^{Subsidy} > I^{Patent}$ and $I^{Subsidy} > I^{Buyout}$.

Using the derived expression of $I^{Subsidy}$, the welfare of the North under a domestic subsidy can be calculated from equation (10) as

$$\begin{aligned} W^{N,Subsidy} &= \int_0^{I^{Subsidy}} s^{o,N}(I)dI + \int_0^{I^{Subsidy}} \pi^S(I)dI - I^{Subsidy} \\ &= \int \gamma n(f-gI)dI + \int \frac{1}{2}(1-\gamma)n(f-gI)dI - \frac{nf(1+\gamma)-2}{ng(1+\gamma)} \\ &= \frac{[nf(1+\gamma)-2]^2}{4ng(1+\gamma)}. \end{aligned} \tag{B.11}$$

The associated welfare of the South can be calculated as

$$\begin{aligned} W^{S,Subsidy} &= \int_0^{I^{Subsidy}} s^{\pi,S}(I)dI \\ &= \int \frac{1}{4}(1-\gamma)n(f-gI)dI \\ &= \frac{(1-\gamma)\left[n^2f^2(1+\gamma)^2-4\right]}{8ng(1+\gamma)^2}. \end{aligned} \tag{B.12}$$

B.4 Proof of Proposition 1

The proof of Proposition 1 is obtained by comparing the total welfare of the North under a domestically-financed buyout (equation B.8) with the welfare obtained under a system of global patent protection (equation B.5). Taking the difference of the two expressions and simplifying the result leads to

$$\begin{aligned} W^{N,Buyout} - W^{N,Patent} &= \frac{(\gamma nf-1)^2}{2\gamma ng} - \frac{nf-2}{8ng}\Big[(2+\gamma)(nf+2)-8\Big] \\ &= \frac{\gamma n^2f^2(3\gamma-2)+4(\gamma-1)^2}{8\gamma ng}. \end{aligned} \tag{B.13}$$

The numerator in expression (B.13), on which the sign depends, is a quadratic function of γ, and may be positive or negative, depending on the parameter values. The existence of a unique cutoff value $\overline{\gamma}_1$ (as described in Proposition 1), which determines whether the North prefers a buyout or a patent system, can be derived as follows. Setting the numerator in equation (B.13) equal to zero, and transforming it into the standard quadratic form gives

$$\gamma^2 - \frac{2n^2f^2+8}{3n^2f^2+4}\gamma + \frac{4}{3n^2f^2+4} = 0. \tag{B.14}$$

Since the leading coefficient is positive, the parabola opens upward. Moreover, the two roots are given by

$$\overline{\gamma}^{-,+} = \frac{n^2f^2+4 \mp nf\sqrt{n^2f^2-4}}{3n^2f^2+4}. \tag{B.15}$$

This implies that the difference $W^{N,Buyout} - W^{N,Patent}$ in equation (B.13) is negative for all values $\gamma \in (\overline{\gamma}^-, \overline{\gamma}^+)$ and is positive for $\gamma > \overline{\gamma}^+$ and $\gamma < \overline{\gamma}^-$. In addition, it can be shown (see below) that all feasible values of γ are greater than $\overline{\gamma}^-$. Hence, whether $W^{N,Buyout}$ is greater or smaller than $W^{N,Patent}$ is determined by the single cutoff value $\overline{\gamma}^+$. Setting $\overline{\gamma}_1 = \overline{\gamma}^+$ then provides the proof of Proposition 1.

To complete the proof, we now show that all feasible values of γ must be greater than $\overline{\gamma}^-$. This follows from two parameter value restrictions that arise endogenously in the model from the fact that the investment level can never be negative. From $I^{Patent} > 0$ it follows that $nf > 2$ (see equation B.4). And from $I^{Buyout} > 0$ it follows that $\gamma > \frac{1}{nf}$ (see equation B.7). Using these two restrictions, it is possible to verify that the first root, $\overline{\gamma}^-$, is always smaller than $\frac{1}{nf}$, and thus smaller than the feasible range of values of γ. Starting with

$$\frac{n^2f^2+4-nf\sqrt{n^2f^2-4}}{3n^2f^2+4} < \frac{1}{nf}, \tag{B.16}$$

simplifying the expression leads to

$$n^3f^3 + 4nf - n^2f^2\sqrt{n^2f^2-4} - 3n^2f^2 - 4 < 0. \tag{B.17}$$

The expression on the left-hand side of this inequality equals zero if $nf = 2$ and is strictly smaller than zero if $nf > 2$.[27] Together with the fact that $\gamma > \frac{1}{nf}$, it thus holds that $\gamma > \frac{1}{nf} > \overline{\gamma}^-$ so that there are no feasible values of γ that are smaller than $\overline{\gamma}^-$. Whether $W^{N,Buyout}$ is greater or smaller than $W^{N,Patent}$ is therefore determined by the single cutoff value $\overline{\gamma}_1 = \overline{\gamma}^+$.

Notice also that equation (B.15) together with the parameter restriction $nf > 2$ implies that $\overline{\gamma}^+ \in (\frac{1}{2}, \frac{2}{3})$.[28] Given that $I^{Buyout} > I^{Patent}$ whenever $\gamma > 0.5$ (see Section B.2), this implies that $I^{Buyout} > I^{Patent}$ always holds when the North prefers a buyout over patents (i.e., when $\gamma > \overline{\gamma}_1$).

[27] This can easily be verified (e.g., numerically) by rewriting the expression as a function of a single variable $x = nf$.

[28] The lower bound, $\overline{\gamma}^+ > \frac{1}{2}$ follows directly from applying the restriction $nf > 2$ to equation (B.15). The upper bound follows from the fact that $\lim_{nf\to\infty} \overline{\gamma}^+ = \frac{2}{3}$.

In addition, we also show here that, for $\gamma < \overline{\gamma}_1$, global welfare is higher under a buyout than under a patent system. The change in the North's welfare when moving from a patent system to a buyout is given by equation (B.13). The corresponding change in the South's welfare can be calculated as

$$W^{S,Buyout} - W^{S,Patent} = \frac{(1-\gamma)(\gamma^2 n^2 f^2 - 1)}{2\gamma^2 ng} - \frac{(1-\gamma)(n^2 f^2 - 4)}{8ng} = (1-\gamma)\frac{3\gamma^2 n^2 f^2 + 4\gamma^2 - 4}{8\gamma^2 ng}. \tag{B.18}$$

Adding up the expressions in equations (B.13) and (B.18) shows that the change in global welfare when moving from a patent system to a buyout is given by

$$W^{W,Buyout} - W^{W,Patent} = \frac{\gamma n^2 f^2 (3\gamma - 2) + 4(\gamma-1)^2}{8\gamma ng} + (1-\gamma)\frac{3\gamma^2 n^2 f^2 + 4\gamma^2 - 4}{8\gamma^2 ng} = \frac{\gamma^2(n^2 f^2 - 4) + 4(2\gamma - 1)}{8\gamma^2 ng}. \tag{B.19}$$

This expression is positive if $\gamma > \frac{1}{2}$ (recall that $nf > 2$ because $I^{Patent} > 0$). As derived above, it also holds that $\overline{\gamma}^+ \in (\frac{1}{2}, \frac{2}{3})$. Thus, for every cutoff value $\overline{\gamma}_1 = \overline{\gamma}^+$ there exists a range of values $\gamma \in (\frac{1}{2}, \overline{\gamma}_1)$ for which the North prefers a patent system over a buyout although a buyout would increase global welfare relative to a patent system. This completes the proof or Proposition 1. □

B.5 Proof of Proposition 2

The proof of Proposition 2 is obtained by comparing the total welfare of the North under a domestic subsidy with the welfare obtained under global patent protection or under a domestically-financed buyout.

Taking the difference of the expressions in equation (B.11) and equation (B.5) shows that the welfare gain to the North when moving from a patent system to a domestic subsidy is given by

$$W^{N,Subsidy} - W^{N,Patent} = \frac{[nf(1+\gamma) - 2]^2}{4ng(1+\gamma)} - \frac{nf-2}{8ng}\Big[(2+\gamma)(nf+2) - 8\Big] = \frac{\gamma(n^2 f^2 - 4) + \gamma^2(n^2 f^2 + 4)}{8ng(1+\gamma)}. \tag{B.20}$$

This expression is positive given that $nf > 2$ (recall that this parameter restriction follows from $I^{Patent} > 0$). Thus, the North always prefers a domestic subsidy to a patent system.

Taking the difference of the expressions in equation (B.11) and equation (B.8) shows that the welfare gain to the North when implementing a subsidy rather than a domestically-financed buyout is given by

$$W^{N,Subsidy} - W^{N,Buyout} = \frac{[nf(1+\gamma)-2]^2}{4ng(1+\gamma)} - \frac{\gamma nf(\gamma nf-2)+1}{2\gamma ng}$$
$$= (1-\gamma)\frac{n^2f^2\gamma(1+\gamma)-2}{4\gamma ng(1+\gamma)}. \tag{B.21}$$

This expression is positive if it holds that

$$n^2f^2\gamma(1+\gamma) > 2. \tag{B.22}$$

Using the two parameter restrictions, $\gamma > \frac{1}{nf}$ and $nf > 2$, derived above, it holds that

$$n^2f^2\gamma(1+\gamma) > nf+1 > 2. \tag{B.23}$$

Thus, the expression in equation (B.21) is always positive and the North prefers a subsidy to a domestically-financed buyout.

For the South, taking the difference of the expressions in equation (B.12) and equation (B.6) leads to

$$W^{S,Subsidy} - W^{S,Patent} = \frac{(1-\gamma)[n^2f^2(1+\gamma)^2-4]}{8ng(1+\gamma)^2} - \frac{(1-\gamma)(n^2f^2-4)}{8ng}$$
$$= \frac{\gamma(1-\gamma)(2+\gamma)}{2ng(1+\gamma)^2}. \tag{B.24}$$

Since this expression is positive for all feasible values of γ (recall that $\gamma < 1$), the welfare of the South is always higher under a subsidy in the North than under a global patent regime. Moreover, given that a domestic subsidy in the North increases welfare both in the North and the South compared to a patent system, it also follows that global welfare is higher under the subsidy than under a global patent regime.

The global welfare comparison between a subsidy in the North and a domestically-financed buyout is less straightforward as the outcome depends on the parameter values. Taking the difference of the expressions in equation (B.12) and equation (B.9) shows that the welfare gain to the South when the North moves from a buyout to a domestic subsidy is given by

$$W^{S,Subsidy} - W^{S,Buyout} = \frac{(1-\gamma)[n^2f^2(1+\gamma)^2-4]}{8(1+\gamma)^2ng} - \frac{(1-\gamma)(\gamma^2n^2f^2-1)}{2\gamma^2ng}$$
$$= (1-\gamma)\frac{4(1+2\gamma)-3n^2f^2\gamma^2(1+\gamma)^2}{8ng\gamma^2(1+\gamma)^2}. \tag{B.25}$$

Adding up the expressions in equations (B.21) and (B.25) shows that the change in global welfare when the North moves from a domestically-financed buyout to a subsidy is given by

$$W^{W,Subsidy} - W^{W,Buyout} = (1-\gamma)\frac{n^2f^2\gamma(1+\gamma)-2}{4\gamma ng(1+\gamma)} + (1-\gamma)\frac{4(1+2\gamma)-3n^2f^2\gamma^2(1+\gamma)^2}{8ng\gamma^2(1+\gamma)^2}$$
$$= (1-\gamma)\frac{4(1+\gamma-\gamma^2)-n^2f^2\gamma^2(1+\gamma)^2}{8ng\gamma^2(1+\gamma)^2}. \tag{B.26}$$

This expression is negative if it holds that

$$4(1+\gamma-\gamma^2) - n^2f^2\gamma^2(1+\gamma)^2 < 0. \tag{B.27}$$

Using the parameter restriction $nf > 2$ derived above, inequality (B.27) is fulfilled for all feasible values of n and f if

$$4(1+\gamma-\gamma^2) - 4\gamma^2(1+2\gamma+\gamma^2) < 0. \tag{B.28}$$

Dividing both sides of the inequality by 4 and simplifying the expression on the left-hand side leads to

$$1+\gamma-2\gamma^2-2\gamma^3-\gamma^4. \tag{B.29}$$

It is easy to verify (e.g., numerically) that this function has a single root on the interval $(0,1)$. Let this root be denoted by $\overline{\gamma}_2$. The function (B.29) is positive for $\gamma \in (0, \overline{\gamma}_2)$ and is negative for $\gamma \in (\overline{\gamma}_2, 1)$. Thus, if $\gamma > \overline{\gamma}_2$, the expression in equation (B.26) is negative so that global welfare is higher under a buyout than under a domestic subsidy. Conversely, if $\gamma < \overline{\gamma}_2$, then global welfare is higher under a domestic subsidy than under a buyout. This completes the proof or Proposition 2. □

B.6 Proof of Proposition 3

As established by Proposition 2, the equilibrium outcome if international surplus transfers are not possible always consists of a domestic subsidy in the North. For the proof of Proposition 3 it is thus sufficient to compare each country's welfare obtained under a buyout with international transfer with the respective welfare obtained under the domestic subsidy. As described in Subsection 2.3.4, we consider two cases of a buyout with transfer, one where the North acts as the principal and offers a contract to the South, and one where the South is the principal and offers a contract to the North.

If the North sets up the contract, then the size of the transfer T and the achieved level of innovation $I^{Transfer}$ are determined by the North's optimization problem given by equations (12) to (14). For ease of notation, let $\hat{T}_N$ and $\hat{I}_N$ denote the values of T and $I^{Transfer}$ if the contract is offered by the North. Based on the results in Proposition 2, it holds that $\tilde{W}^S = W^{S,Subsidy}$ and $\tilde{W}^N = W^{N,Subsidy}$. Assuming that the South agrees to a transfer at its point of indifference between a buyout with transfer and the alternative of a domestic subsidy, the North optimizes as follows:

$$\max_{\hat{T}_N, \hat{I}_N} \quad W^{N,Transfer} = \int_0^{\hat{I}_N} \gamma n(f - gI)dI + \hat{T}_N - \hat{I}_N \tag{B.30}$$

$$s.t. \int_0^{\hat{I}_N} (1-\gamma)n(f - gI)dI - \hat{T}_N \geq W^{S,Subsidy}. \tag{B.31}$$

Using the expression of $W^{S,Subsidy}$ from equation (B.12), the corresponding Lagrangian is

$$\mathcal{L} = \int_0^{\hat{I}_N} \gamma n(f-gI)dI + \hat{T}_N - \hat{I}_N - \lambda \left[\int_0^{\hat{I}_N} (1-\gamma)n(f-gI)dI - \hat{T}_N - \frac{(1-\gamma)\left[n^2 f^2 (1+\gamma)^2 - 4\right]}{8ng(1+\gamma)^2} \right].$$

Taking the first order conditions with respect to $\hat{T}_N$ and $\hat{I}_N$ leads to

$$\hat{T}_N = (1-\gamma)\frac{(3n^2 f^2 - 4)(1+\gamma)^2 + 4}{8ng(1+\gamma)^2}, \tag{B.32}$$

$$\hat{I}_N = \frac{nf - 1}{ng}. \tag{B.33}$$

Note that $\hat{T}_N$ is strictly positive (recall that $nf > 2$ because $I^{Patent} > 0$). The level of investment $\hat{I}_N$ corresponds to the world optimum (i.e., the investment level chosen by a social planner maximizing global welfare).

The resulting welfare of each country is given by

$$W^{N,Transfer} = \frac{(1+\gamma)^2 \left[3n^2 f^2 (1+\gamma) - 8nf + 4\right] + 4(1-\gamma)}{8ng(1+\gamma)^2}, \tag{B.34}$$

$$W^{S,Transfer} = W^{S,Subsidy}. \tag{B.35}$$

It is easy to verify that $W^{N,Transfer} > W^{N,Subsidy}$, so the North will always choose to implement a buyout if transfers are possible. Moreover, adding up $W^{N,Transfer}$ and $W^{S,Transfer}$ shows that the global welfare in this case is given by

$$W^{W,Transfer} = \frac{(nf-1)^2}{2ng}, \tag{B.36}$$

which equals the first-best global welfare that would also be achieved by a benevolent world social planner.

If the contract is instead set up by the South, then T and $I^{Transfer}$ are determined by the South's optimization problem:

$$\max_{\hat{T}_S, \hat{I}_S} \quad W^{S,Transfer} = \int_0^{\hat{I}_S} (1-\gamma)n(f-gI)dI - \hat{T}_S \tag{B.37}$$

$$s.t. \int_0^{\hat{I}_S} \gamma n(f-gI)dI + \hat{T}_S - \hat{I}_S \geq W^{N,Subsidy}, \tag{B.38}$$

where the subscript S indicates that the contract is offered by the South. Using the expression of $W^{N,Subsidy}$ from equation (B.11), the corresponding Lagrangian is

$$\mathcal{L} = \int_0^{\hat{I}_S} (1-\gamma)n(f-gI)dI - \hat{T}_S - \lambda \left[\int_0^{\hat{I}_S} \gamma n(f-gI)dI + \hat{T}_S - \hat{I}_S - \frac{[nf(1+\gamma)-2]^2}{4ng(1+\gamma)} \right].$$

Taking the first order conditions with respect to $\hat{T}_S$ and $\hat{I}_S$ leads to

$$\hat{T}_S = (1-\gamma)\frac{n^2 f^2(1+\gamma) - 2\gamma}{4ng(1+\gamma)}, \tag{B.39}$$

$$\hat{I}_S = \frac{nf-1}{ng}. \tag{B.40}$$

The level of investment $\hat{I}_S$ is the same as $\hat{I}_N$. For the transfer, using once more the fact that $nf > 2$ shows that $\hat{T}_S < \hat{T}_N$.

The resulting welfare of each country is given by

$$W^{N,Transfer} = W^{N,Subsidy}, \tag{B.41}$$

$$W^{S,Transfer} = (1-\gamma)\frac{n^2 f^2(1+\gamma) - 2}{4ng(1+\gamma)}. \tag{B.42}$$

It is easy to verify that $W^{S,Transfer} > W^{S,Subsidy}$, so the South will always choose to implement a buyout with transfers if it has the chance to do so. Moreover, adding up $W^{N,Transfer}$ and $W^{S,Transfer}$ shows that the global welfare again equals the first-best welfare from equation (B.36). This completes the proof or Proposition 3. □

B.7 Proof of Proposition 4

With resale, the North only obtains a fraction $r \in (0,1)$ of the monopoly profit associated with each innovation from the Southern market. The achieved level of innovation, I^{Resale}, in this case is determined by

$$s^{o,N}(I^{Resale}) + (1-r)\pi^S(I^{Resale}) = 1. \tag{B.43}$$

Plugging in the expressions of $s^{o,N}$ and π^S from equations (3) and (B.1), and solving for I, shows that the optimal level of research investment under a subsidy with resale is given by

$$I^{Resale} = \frac{nf[1+\gamma+r(\gamma-1)]-2}{ng[1+\gamma+r(\gamma-1)]}. \tag{B.44}$$

Given that $r(\gamma - 1) \in (-1, 0)$, it follows that $I^{Resale} < I^{Subsidy}$ for all $r \in (0, 1)$.

Using expression (B.44) in equation (15), the North's welfare under a domestic subsidy with resale can be calculated as

$$\begin{aligned} W^{N,Resale} &= \int_0^{I^{Resale}} s^{o,N}(I)dI + (1-r)\int_0^{I^{Resale}} \pi^S(I)dI - I^{Resale} \\ &= \int \gamma n(f-gI)dI + (1-r)\int \frac{1}{2}(1-\gamma)n(f-gI)dI - \frac{nf[1+\gamma+r(\gamma-1)]-2}{ng[1+\gamma+r(\gamma-1)]} \\ &= \frac{[nf(1+\gamma+r\gamma-r)-2]^2}{4ng(1+\gamma+r\gamma-r)}. \end{aligned} \tag{B.45}$$

Taking the difference of the expressions in equation (B.45) and equation (B.11) shows that the welfare loss to the North resulting from resale in the case of a domestic subsidy is given by

$$W^{N,Resale} - W^{N,Subsidy} = r(1-\gamma)\left[4 - n^2f^2(1+\gamma)(1+\gamma+r\gamma-r)\right]. \tag{B.46}$$

Since the investment level cannot be negative, it follows from $I^{Resale} > 0$ that $(1 + \gamma + r\gamma - r) > \frac{2}{nf}$. Together with the parameter restriction $nf > 2$ (derived in Appendix B.4), this implies that the term in squared brackets in equation (B.46) is negative. It thus holds that $W^{N,Resale} < W^{N,Subsidy}$ for all $r \in (0, 1)$.

The result that $W^{N,Resale} > W^{N,Buyout}$ for all $r \in (0, 1)$ can be derived as follows. Taking the difference of the expressions in equation (B.45) and equation (B.8) gives

$$W^{N,Resale} - W^{N,Buyout} = (\gamma-1)(r-1)\left[\gamma n^2f^2(1+\gamma+r\gamma-r) - 2\right]. \tag{B.47}$$

Using the parameter restrictions $(1+\gamma+r\gamma-r) > \frac{2}{nf}$ (derived above) and $\gamma > \frac{1}{nf}$ (derived in Appendix B.4), it follows that the term in squared brackets in equation (B.47) is positive. Given that $\gamma \in (0, 1)$ it thus holds that $W^{N,Resale} > W^{N,Buyout}$ for all $r \in (0, 1)$.

If $r = 1$ (i.e., perfect resale), then foreign profits to the North are fully eliminated. The optimal strategy of the North in this case mirrors the one under a domestically-financed patent buyout. To see this, just notice that the North's surplus under perfect resale takes the same form as the expression in equation (9), and that the optimal level of innovation is determined by the same condition (equation 6) as under a domestically-financed buyout. With perfect resale, the North is thus indifferent between a subsidy and a domestically-financed patent buyout.

Whether the North fares better under a subsidy with resale or under global patent protection depends on the parameter values. To see this, consider a switch from patent protection to a domestic subsidy with resale. Under a subsidy, resale reduces the North's profit extracted from the Southern market. This effect is less important, the larger γ is (i.e., the smaller the share of the South in the global market is). At the same time, moving from patents to a subsidy eliminates static deadweight loss in the North's home market. The associated increase in welfare is larger, the higher γ is. Thus, for given values f, g, n, and r, larger values of γ make a subsidy under resale more attractive to the North relative to patents (it is also possible to verify this result numerically, as we have done for different parameter value combinations).

The last part of Proposition 4 states that the presence of resale leaves intact the result that, if international surplus transfers are possible, the equilibrium outcome consists of a buyout which stipulates the globally efficient level of innovation. This follows directly from the fact that the first-order conditions that determine the level of innovation (i.e., the values of $\hat{I}_N$ and $\hat{I}_S$ in Appendix B.6) remain unaffected by the introduction of the parameter r to the North's objective function. At the same time, the presence of resale reduces the North's welfare under a subsidy, so that restriction (B.38) is relaxed, affecting the size of T and thus the distribution of welfare (analogously for restriction (B.31) if the North acts as the principal). This completes the proof or Proposition 4. □

B.8 Proof of Proposition 5

Given that countries' welfare is additively separable in each sector, Proposition 2 is sufficient to establish that global patent protection paired with a domestic subsidy will be a dominant strategy for both countries. Specifically, recall that Proposition 2 establishes that a subsidy regime will always strongly (weakly) dominate a patent regime for the innovating (recipient) country. Therefore, we can safely exclude *Patent* from the strategy space, which leaves us with a 2-by-2 game in which each country chooses *Subsidy* or *Buyout* for its sector.

Let the simultaneous one-period game be between players N and S, which innovate in sectors x and y respectively. Moreover, let W_{ik}^{r} denote the welfare obtained by player $i \in \{N, S\}$ from sector $k \in \{x, y\}$ under the innovation regime $r \in \{Subsidy, Buyout\}$. The payoff matrix is given as follows.

Table A1: Payoffs with two innovating countries

		S: *Subsidy*	S: *Buyout*
N	*Subsidy*	$(W_{N,x}^{Subsidy} + W_{N,y}^{Subsidy},\quad W_{S,x}^{Subsidy} + W_{S,y}^{Subsidy})$	$(W_{N,x}^{Subsidy} + W_{N,y}^{Buyout},\quad W_{S,x}^{Subsidy} + W_{S,y}^{Buyout})$
	Buyout	$(W_{N,x}^{Buyout} + W_{N,y}^{Subsidy},\quad W_{S,x}^{Buyout} + W_{S,y}^{Subsidy})$	$(W_{N,x}^{Buyout} + W_{N,y}^{Buyout},\quad W_{S,x}^{Buyout} + W_{S,y}^{Buyout})$

Proposition 2 establishes that, within the sector it innovates in, the North prefers a subsidy regime to a buyout (recall that sectors are non-overlapping and welfare is additively separable in sectors). It thus holds that $W_{N,x}^{Subsidy} > W_{N,x}^{Buyout}$. By symmetry, for the innovating South it holds that $W_{S,y}^{Subsidy} > W_{S,y}^{Buyout}$. From the payoff matrix (Table A1), it can be seen that this results in a unique $\{Subsidy, Subsidy\}$ equilibrium, as each country is better off subsidizing its own sector regardless of what the other chooses to do.

Proposition 2 can also be used to see that the implications for world welfare are indeterminate between $\{Subsidy, Subsidy\}$ and $\{Buyout, Buyout\}$ when a country uses buyouts to maximize only its own surplus. For innovation in the North's sector x (for which the South is a non-innovating player), it has been established that the sum of the two countries' welfares from a subsidy regime may be greater or smaller than the sum of their combined welfare from a buyout regime, depending on the parameter values of the model (see the proof of Proposition 2 in Appendix B.5). In terms of the above payoff matrix, this translates to

$$W_{N,x}^{Subsidy} + W_{S,x}^{Subsidy} \lesseqgtr W_{N,x}^{Buyout} + W_{S,x}^{Buyout}. \tag{B.48}$$

By symmetry, for the South's sector y we obtain

$$W_{N,y}^{Subsidy} + W_{S,y}^{Subsidy} \lesseqgtr W_{N,y}^{Buyout} + W_{S,y}^{Buyout}. \tag{B.49}$$

Notice that world welfare for $\{Subsidy, Subsidy\}$ is the sum of the left-hand sides of the two above inequalities, while world welfare for $\{Buyout, Buyout\}$ is the sum of the two right-hand sides. Therefore, it is in general indeterminate whether the $\{Subsidy, Subsidy\}$ equilibrium is Pareto superior or inferior to a mutual buyout where each country maximizes its own surplus.

The second part of Proposition 5 states that the game can devolve into a Prisoner's Dilemma if the two countries are cooperative in their buyout strategy (i.e., using equation (17) as their optimality condition). By construction, $\{Buyout, Buyout\}$ now maximizes world welfare (note that, to keep notation simple, we still use the same notation for buyouts as above, although the rest of this section focuses on cooperative buyouts). However, for a Prisoner's Dilemma to hold, it is also necessary that (i) *Subsidy* remains a dominant strategy for each country, and (ii) each country would be better off by moving to $\{Buyout, Buyout\}$.

To see that *Subsidy* remains a dominant strategy we can compare (for the North, and then the South by symmetry) $W_{N,x}^{Subsidy}$ with $W_{N,x}^{Buyout}$ when the buyout is cooperative. To make the distinction between the sectors clear, let the parameters be f_k, g_k where $k \in \{x, y\}$ (although this does not affect within-sector welfare comparisons). Then, $W_{N,x}^{Subsidy}$ can be calculated in accordance with equation (B.11) as

$$W_{N,x}^{Subsidy} = \frac{[nf_x(1+\gamma) - 2]^2}{4ng_x(1+\gamma)}. \tag{B.50}$$

To calculate $W_{N,x}^{Buyout}$, we note that the globally optimal level of innovation in sector x is $I_x^* = \frac{nf_x - 1}{ng_x}$ (see equation B.33), so that

$$
\begin{aligned}
W_{N,x}^{Buyout} &= S_x^{o,N}(I_x^*) - I_x^* \\
&= \int_0^{I_x^*} s_x^{o,N}(I_x) dI_x - I_x^* \\
&= \int_0^{I_x^*} \gamma n(f_x - g_x I) dI_x - \frac{nf_x - 1}{ng_x} \\
&= \frac{(nf_x - 1)[\gamma(nf_x + 1) - 2]}{2ng_x}.
\end{aligned} \tag{B.51}
$$

Taking the difference of the last two equations gives

$$
W_{N,x}^{Subsidy} - W_{N,x}^{Buyout} = \frac{(1-\gamma)\left[n^2 f_x^2 (1+\gamma) - 2\gamma\right]}{4ng_x(1+\gamma)}. \tag{B.52}
$$

The right-hand side of equation (B.52) is strictly positive because $n^2 f_x^2(1+\gamma) > 2\gamma$ given that $nf_x > 2$. By symmetry, for the South it holds that $W_{S,y}^{Subsidy} > W_{S,y}^{Buyout}$ when the buyout is cooperative (i.e., the South acts like a global welfare maximizer in sector y). Therefore, $\{Subsidy, Subsidy\}$ remains the unique equilibrium.

It remains to be shown that both countries could gain from moving to (non-equilibrium) $\{Buyout, Buyout\}$. For the North, this would imply that its welfare under a mutual subsidy is lower than its welfare under a mutual buyout:

$$
W_{N,x}^{Subsidy} + W_{N,y}^{Subsidy} < W_{N,x}^{Buyout} + W_{N,y}^{Buyout}, \tag{B.53}
$$

and analogously for the South.

The welfare of the North from its own x sector under a subsidy and a buyout regime is given by the expressions in equations (B.50) and (B.51), respectively. To calculate the welfare of the North from the y sector under each possible innovation regime implemented by the South, it is first necessary to calculate how much the South would innovate under each regime. Under a subsidy, the South would innovate according to the optimality condition $s^{o,S}(I^{Subsidy}) + \pi^N(I^{Subsidy}) = 1$, where $s^{o,S}(I) = (1-\gamma)n(f_y - g_y I)$ and $\pi^N(I) = \frac{1}{2}s^{o,N} = \frac{1}{2}\gamma n(f_y - g_y I)$. The result is

$$
I_y^{Subsidy} = \frac{nf_y(2-\gamma) - 2}{ng_y(2-\gamma)}. \tag{B.54}
$$

It can be checked that this is consistent with the level of innovation under subsidy for the North (equation B.10) but with γ being replaced by $(1-\gamma)$ as the relevant population share of the innovating country. Subsequently, the welfare of the North under such a regime can be calculated as

$$\begin{aligned} W_{N,y}^{Subsidy} &= \int_0^{I_y^{Subsidy}} s^{\pi,N}(I)dI \\ &= \int \frac{1}{4}\gamma_y n(f_y - g_y I)dI \\ &= \frac{\gamma_y\left[nf_y(2-\gamma_y)-2\right]}{2ng_y(2-\gamma_y)^2}. \end{aligned} \tag{B.55}$$

In contrast, under a cooperative buyout the South would innovate to the level $I_y^* = \frac{nf_y-1}{ng_y}$. The welfare of the North under such a regime would be

$$\begin{aligned} W_{N,y}^{Buyout} &= \int_0^{I_y^*} s_y^{o,N}(I_y)dI_y \\ &= \int_0^{I_y^*} \gamma n(f_y - g_y I)dI_y \\ &= \frac{\gamma\left[n^2 f_y^2 - 1\right]}{2ng_y}. \end{aligned} \tag{B.56}$$

Taking the difference of the last two equations gives

$$W_{N,y}^{Subsidy} - W_{N,y}^{Buyout} = \gamma\frac{nf_y(2-\gamma) - 2 - (2-\gamma)^2(n^2 f_y^2 - 1)}{2ng_y(2-\gamma)^2}. \tag{B.57}$$

It can easily be verified that the numerator of the right-hand side of equation (B.57) is negative for all $nf > 2$, thereby confirming that each country prefers the other to institute a globally welfare maximizing buyout.

As a last step, the condition (B.53) for the Prisoner's Dilemma can be rewritten as

$$\left(W_{N,x}^{Subsidy} - W_{N,x}^{Buyout}\right) + \left(W_{N,y}^{Subsidy} - W_{N,y}^{Buyout}\right) < 0, \tag{B.58}$$

where plugging in the expressions from equations (B.52) and (B.57) gives

$$\frac{(1-\gamma)\left[n^2 f_x^2(1+\gamma) - 2\gamma_x\right]}{4ng_x(1+\gamma)} + \gamma\frac{nf_y(2-\gamma) - 2 - (2-\gamma)^2(n^2 f_y^2 - 1)}{2ng_y(2-\gamma)^2} < 0. \tag{B.59}$$

When $f_y = f_x$ and $g_y = g_x$, so that both sectors have the same relationship between the level of innovation and the consumer surplus function, the expression on the left-hand side of inquality (B.59) reduces to

$$\frac{-n^2 f^2(\gamma-2)^2(\gamma+1)(3\gamma-1) - 2\gamma nf(\gamma-2)(\gamma-1) - 4\gamma(1-3\gamma+4\gamma^2-\gamma^2)}{4nf(1+\gamma)(2-\gamma)^3}. \tag{B.60}$$

The denominator of expression (B.60) is positive. It can also be verified that the numerator is negative for all $\gamma \in (0,1)$, so that the overall expression is always negative. Thus, there exist parameter value combinations for which the North is worse off in the subsidy equilibrium than under a mutual cooperative buyout. By symmetry, the same can be established for the South. This completes the proof for the Prisoner's Dilemma.

Finally, the last part of Proposition 5 states that only transfers outside the game can move the world to the globally optimal buyout regime. This follows directly from $\{Subsidy, Subsidy\}$ being a unique but Pareto inferior equilibrium. This completes the proof of Proposition 5. $\square$