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The Geoeconomics of Trade Infrastructure and the Innovation Competition between China and the US

Kai A. Konrad*

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Abstract

China’s high investment in foreign trade structures and the extraordinary innovation efforts of their firms are closely related. They can be explained as a subgame perfect equilibrium outcome of an asymmetric strategic-trade model, in which infrastructure investment renders successful innovation by exporting companies in China more profitable, and in which China and the US have to choose different roles in this innovation competition. That China ends up in the role of the more active investor and the more innovative competitor in this process can be explained by China’s larger export sector and by their competition policy, which is more focused on national champions.

Keywords: Strategic trade policy, infrastructure investment, innovation contests, global patent races, China-US conflict

JEL classification numbers: F43, F51, F55, F63, H56

*Corresponding author. Address: Max Planck Institute for Tax Law and Public Finance, Marstallplatz 1, D-80539 Munich. E-mail: kai.konrad@tax.mpg.de. Orcid ID: 0000-0002-2225-2271. I thank Michael Lanschützer for most valuable comments. The usual caveat applies.

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1 Introduction

We study the nexus between China’s large governmental investments in trade-facilitating infrastructure, total volumes of goods exports from China and from the US, the innovation activities of firms in the two countries, and the countries’ industrial policies on innovation and competition. A formal game theory analysis of competition between the two big countries here supports the following narrative: trade-facilitating investment improves a country’s prospects for international market access. This gives the export-oriented firms in this country stronger R&D incentives. These are also anticipated by firms in the other country and this weakens firms’ R&D investment incentives there. Such investments are therefore strategic instruments in the international innovation competition. Trade-facilitating investments are asymmetric in the equilibrium: One country takes a stand-alone role and tends to invest little in trade infrastructure. The other country takes a more aggressive role, investing larger amounts and gains considerable benefits in export markets due to the innovation dynamics that emerge from the investment. The model analysis also reveals that the two countries’ role choices are influenced by the existing differences in the countries’ established export sectors and by differences in their internal industrial policies. For instance, national governmental industry policy that produces national champions and counteracts national research duplication puts the country in a position to acquire the more attractive role with high trade-facilitating investments. In expectation, in equilibrium this country wins the rents from international trade on newly innovated goods. The other country is more likely to end up in the less attractive stand-alone role and cannot participate in the innovation rents. The second relevant dimension for countries’ role choices is the size difference of the established and pre-existing goods-export sectors. A larger pre-existing export sector is conducive for this country to pick up the more attractive role as the major investor in trade infrastructure and as the more active and successful innovator in the competition for international innovation rents.

Several stylized facts correspond to this framework.

China’s high investments in trade-facilitating infrastructure. Prominent examples of China’s major trade-facilitating governmental investments in-
clude the formation of trade agreements such as the Comprehensive Economic Partnership (RCEP), physical infrastructure investment such as the Belt & Road Initiative, institution building such as the founding of the Asian Infrastructure Investment Bank (AIIB), and investments in ownership and control of trade infrastructure, such as the acquisition of ports and airports in target countries. Chang, Li, Cheong, and Goh (2021, p. 13) find evidence that China’s FDI is directed at developing sales markets in the face of domestic overcapacity, developing or expanding access to raw materials, and improving access to what could be called cheap labor. These activities improve China’s market integration, remove trade obstacles and thereby reduce trade costs between China and possible export markets.

The empirical link between infrastructure investments and trade costs. Limão and Venables (2001) provide evidence on the role of infrastructure investment for lowering trade costs. They attribute a significant role of such investments to a country’s ability to participate in the global value creation process. A broad literature demonstrates the close link between the amount of trade and the various infrastructure goods that facilitate or enable it (see, e.g., Francois and Manchin, 2013). It is important to note that what matters is the country’s trade costs relative to that of the competitor(s). Anderson and van Wincoop (2004) emphasize: “The main insight from the theory is that bilateral trade depends on relative trade barriers.”

China’s export sector is larger than the US export sector. China’s export sector is consistently larger than that of the US. China’s export volume on goods reached US-$3.3 trillion in 2021, compared to US exports of only US-$1.75 trillion (see Statista, 2023a, 2023b).

Industrial policy in China: National champions. For China, Yu (2019) describes a tendency of state-owned enterprises to merge and increases in concentration in many industries with the aim of making them ready for a “go global” strategy and explicitly mentions the “national champion” strategy: that is, the formation of strong international competitors. This policy is

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1Similar to this are the findings of Damoah, Giovannetti, and Marvasi (2023) on country characteristics and the intensity of Belt and Road investments.

2For discussions and assessments see also Verma (2022) and Pandit (2022). Furthermore, Groenewegen-Lau and Laha (2023, p.2) write, for instance, “China’s innovation
pursued even though a free-internal-markets policy and internal competition-policy might have evident advantages for economic performance inside China. Our analysis can provide a rationale for such policies.

China’s R&D. China’s R&D investment is growing on a comparatively steep path and will, if current trends are projected into the future, surpass those of the US in a couple of years (for data see OECD, 2022). The flow of patent applications in China shows a similar pattern. For instance, the numbers of transnational patent applications surpassed that of Japan in 2018, and is close to reaching and surpassing the more flat development of US applications (Schmoch and Gehrke, 2022, Figure 3, p. 307).

Our theory suggests that these stylized facts are interdependent, both as explanatory factors and as equilibrium outcomes in the geoeconomic competition between the US and China. The relationship between infrastructure investment, trade costs, and export shares makes governments’ infrastructure investments abroad a means to increase own firm exports and firm profits from exports. Furthermore, lower trade costs provide strong incentives for the private sector in innovation competitions and patent races.

The analysis also uncovers a strategic incentive for higher investment: relative trade-cost advantages provide stronger incentives for home firms in the patent contests and weaken such incentives in the other country. The two large governments can choose their infrastructure investments abroad. They anticipate that these investments will increase the export trade profits of the firms in their country. As these profits go to the successful innovator firms, high investments by their governments make the winning firms more profitable. This can make firms more eager in races for patentable innovations. Governments’ international infrastructure investments do not subsidize exports or R&D spending directly here. The strategic effect is more indirect. These investments lower the cost of trade of a country’s successful home firms, this increases their monopoly rents of winning the patent race, and this has strategic effects in the patent race: “own” firms expend more

system is increasingly hierarchical, resulting in a greater degree of central coordination and control.” Tian (2020, p.4) alludes to China’s industrial policy “to protect and support large state-owned enterprises, and restrict the challenges and competition from small and medium-sized enterprises to the market position of large state-owned enterprises.”
effort on innovation and this discourages the innovation effort of firms in the other competing country.

It turns out that this logic leads to equilibria with asymmetric investment roles by the governments. One of the countries adopts the role of the major investor. As this role is more attractive than the other, it is not always clear which country will adopt this more attractive role. However, initial asymmetries between the US and China in exports and in their industry policies can influence or even determine their role choices. Such important asymmetries include the size of the pre-existing export volumes, and differences in the industrial competition policies in both countries. Overall, the equilibrium logic fits well with the stylized facts: China’s large investments in institutional and physical trade infrastructure with Asia, Africa, and Europe, China’s high and fast-growing expenditure on innovation activities, China’s comparatively large export sector, and China’s national-champions policy.

From an analytical point of view the analysis is related to the literature on strategic foreign trade models. The classic work of Spencer and Brander (1983) and Bagwell and Staiger (1994) studied the role of R&D subsidies in international oligopoly markets. More closely related, Conrad and Seitz (1997) and Normizan and Yasunori (2014) developed Cournot oligopoly models of strategic trade in which infrastructure investment that reduces trade costs is the countries’ strategic variable. This literature alludes to the role of trade costs as a strategic trade instrument. Etro (2011) extends the classic strategic foreign trade model to include the possibility of firms’ market entry. We adopt this element when making firms choose whether to participate one or several of the patent races. These considerations relate to the determinants of patent races in this paper. Konrad (2000) considers a standard strategic trade model in which Cournot markets are replaced by sales contracts that are awarded by way of all-pay contests. The commonality between this paper and the current paper is the emergence of asymmetric equilibria, even for symmetric players. Van Long, Raff, and Stähler (2011) and Takauchi and Mizuno (2022) examine the relationship between production cost-reducing R&D expenditures, transportation costs for exports, and quantity decisions in the Cournot market between domestic producers and foreign importers. In our framework the governments invest in trade-cost
reducing activities. From Haaland and Kind (2008) we adopt the idea that firms in the two competing countries might act as monopolists, where in our context the monopoly power is derived from successful patenting.\(^3\)

The analysis also makes a contribution within the theory of all-pay contests. Patent races have often been analyzed as all-pay contests, starting with the early analyses of Loury (1979) and Dasgupta and Stiglitz (1980). These R&D contests have multiple participants who all undertake activities that impose irreversible and success-independent costs on them (‘all pay’). However, each patent race has only one winner. As in static representations of such patent races by Clark and Konrad (2008) and Fu, Lu, and Lu (2012) we use tools of contest theory. Results here build on the work on the all-pay auction without noise (Hillman and Riley, 1989, and Baye, Kovenock, and de Vries, 1996). Resources employed by the competing firms translate into the firms’ probabilities of winning, thus describing an all-pay auction among the innovative firms. Country governments can help shape this innovation competition: infrastructure investment abroad increases home firms’ monopoly rents from winning the patent races. These investments are themselves efforts within a contest that country governments play out between each other. The infrastructure investments are made when it is not yet clear whether and how many domestic companies will emerge victoriously from the various patent races.

In section 2 we outline the formal framework. In section 3 we solve for the subgame perfect equilibrium. Section 4 has a discussion of the economic policy implications of the results.

\section{The formal framework}

We consider the following international trade/investment/innovation game. There are two big countries, \(A\) and \(B\), and the rest of the world (RoW). Governments \(A\) and \(B\) and firms \(f_A \in F_A\) and \(f_B \in F_B\) in these two countries

\(^3\)The possibly strategic role of trade-cost-reducing infrastructure investment has also received attention in the general trade literature. Yanase and Tawada (2020) and Suga, Tawada, and Yanase (2023) analyze how, in a two-country model, such an infrastructure investment affects the structure and terms of trade in standard trade models.
are players in a game-theory sense. The RoW serves as a price-taking export market, represented by an aggregate demand function.

The two governments make trade-infrastructure investments denoted by \( g_A \in [0, \infty) \) and \( g_B \in [0, \infty) \) in stage 1. These investments are observed by all players and result in per-unit trade costs between the investing country and the RoW. We may think of roads, channels, railway lines, ports, and airports, etc., and of non-physical assets, that all reduce the direct cost of transport between the investing country and the RoW, or facilitate business, for instance, making the enforcement of business contracts easier. It will be useful to define variables \( r_A \) and \( r_B \) by

\[
    r_A \equiv (g_A)^2 \quad \text{and} \quad r_B \equiv (g_B)^2. \tag{1}
\]

These transformations are continuous and strictly monotonically increasing on the domains of \( g_A \) and \( g_B \) and will allow us to consider governments’ choices as choices about \( r_A \) and \( r_B \) that will become economically meaningful further in the analysis. A country’s investment cost \( c(r) \) is a continuous, twice differentiable, and convex function in \( r \) with \( c'(0) = 0 \) and \( \lim_{r \to \infty} c'(r) = \infty \) for \( r \) sufficiently high (e.g., \( \tilde{r} = m_A + m_B + n \), where \( m_A \) and \( m_B \) and \( n \) will be defined further below.)

Consider stage 2. There is a set \( F_A \) of export firms in \( A \) and a set \( F_B \) of export firms in \( B \). These firms own existing patents that can be used to produce and export as a patent-protected monopolies. Let \( m_A \geq 1 \) and \( m_B \geq 1 \) be the number of already existing patents. Furthermore, there are \( n \geq 1 \) new and not yet patented goods \( i = 1, \ldots, n \). Patents for these goods are allocated to firms in patent races between firms at this stage 2. Let \( F^i_A \subseteq F_A \) and \( F^i_B \subseteq F_B \) be the sets of firms that are participating in the innovation race for patent \( i \). These firm sets are exogenously given. We might think of them as determined by the firms’ given technological capabilities for the race for the particular patent/good \( i \). The set of firms \( F^i_A \) is a result of the respective country’s industry policy that is a parameter here and not part of the active choices of firms. Analogously for country \( B \). Due to the independence of each single patent race, we do not need to make assumptions about whether the firm sets \( F^i_A \subseteq \) or \( F^i_B \) are disjoint or overlap. We use \( \#F^i_A \) and \( \#F^i_B \) to denote the number of firms in these sets.
To concentrate on cases with interesting innovation activities, we make two assumptions. First, we assume that, for each patent \(i\), there is at least one firm in each country that can compete for this patent:

\[
\#F^i_A \geq 1 \text{ and } \#F^i_B \geq 1 \text{ for all } i = 1, \ldots, n. \quad (A1)
\]

Second, we assume that there is at least one patent \(i\) for which only one firm from each country is competing for:

\[
\#F^i_A = 1 \text{ and } \#F^i_B = 1 \text{ for at least one } i \in \{1, \ldots, n\}. \quad (A2)
\]

For a given \(i\) each of the innovator firms \(f_A \in F^i_A\) and \(f_B \in F^i_B\) choose their contest efforts \(e^i_A \in [0, \infty)\) and \(e^i_B \in [0, \infty)\), respectively, where the firm’s cost is equal to this effort. Firms pay for their own innovation efforts, and this payment is independent of the firm’s success in the patent race.

The races for each of the \(n\) new patents follow the rules and structure of an all-pay contest without noise: the firm that chooses the higher effort in a particular race wins the respective patent. If several firms tie on the highest effort level chosen, then each wins with the same probability. More formally, let \(e^i_{\text{max}}\) be the largest effort chosen by any of the firms in \(F^i_A\) and \(F^i_B\) for patent \(i\) and let \(z^i\) be the number of firms that choose this highest effort. Then, the win probability for firm \(f_A\) on patent \(i\) is

\[
q^i_{f_A} = \begin{cases} \frac{1}{z^i} & \text{if } e^i_{f_A} = e^i_{\text{max}} \\ 0 & \text{otherwise.} \end{cases}
\]

Stage 2 ends with the contest outcome that assigns the newly patented products to the existing firms.

Stage 3 describes the profit-maximizing production and sales decisions of the firms that own the patents. This applies to the \(m_A\) or \(m_B\) pre-existing patents and to the \(n\) patents that were newly awarded in stage 2. Asymmetries between products are not the focus of the analysis, and we will simply assume that the markets for the \(n + m_A + m_B\) patented goods at stage 3 all

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4This contest success function is well-known inside contest theory and is typically called an all-pay auction/contest without noise (Hillman and Riley, 1989, Baye, Kovenock, and de Vries, 1996). For applications in the context of innovation contests see Kaplan, Luski, and Wettstein (2003), Konrad (2014), and Chowdhury (2017).
follow the same logic and are independent of each other. We can, therefore, be agnostic about which firm in a given country will eventually own patent \( i \), and how many of the new patents will end up at one and the same firm or at different firms. Due to international intellectual property rights protection, all patent holders become the monopolists for the respective product. They produce and export the output to the RoW as monopolists. The holder of patent \( i \) uses the trade infrastructure that connects its home country with the RoW.\(^5\) Demand for good \( i \) in RoW is a downward sloping function. For simplicity, we assume that these demand functions are linear. The demand function that the patent-holding firm in country \( I \in \{A, B\} \) for good \( i \) faces is

\[ p^I_i = 2g^I - x^I_i. \]  

Here, (3) is the price response function between quantity \( x^I_i \) demanded for a per-unit-producer price \( p^I_i \) received by monopolist. The demand function (3) reflects that the owner of patent \( i \) from country \( I \) exports its goods from \( I \) to the rest of the world using the trade infrastructure provided by the government of this very country \( I \). The size of \( g^I \) influences the demand for given producer prices (net of transport cost) as a shift parameter: infrastructure investment is measured in units such that its quantity \( g^I \) reduces the per-per unit trade cost by twice this amount, where the factor 2 is convenient and saves notation later, but is just a normalization assumption. In the absence of any infrastructure \( (g^I = 0) \), the market “disappears” in the sense that the intercept of the demand function becomes zero. Symmetry between goods is assumed and makes the demand functions the same for all patented goods. Unit production costs are normalized to zero for each of the goods to save on notation.

Payoffs of countries \( A \) and \( B \) and of the firms in \( F_A \) and \( F_B \) are straightforwardly defined. Firms’ payoffs are equal to their profits from using their patents, minus possible innovation efforts they expended in stage 2 when trying to win new patents. And in the tradition of the literature on strategic

\(^5\)Think of roads: Producers in \( A \) need roads from their country to the export market in the buyer countries in the rest of the world, whereas the roads from \( B \) to the rest of the world are useless for selling and delivering goods from \( A \), and likewise for production and sales from \( B \).
trade, the payoff of a country is ‘welfare’, defined as the net sum of a country’s rents. These net rents are the sum of the home firms’ payoffs minus the country’s trade-facilitating infrastructure investment.

Some discussion on assumptions might be in order. The description of existing export sectors with $m_A$ and $m_B$ established patents allows us to incorporate and explore the role of the absolute and relative sizes of pre-existing export sectors. These ‘old’ patents benefit from trade-cost reducing investments of the respective country and this benefit co-motivates such investments. We will see that the size and size difference between $m_A$ and $m_B$ are important for which of the countries $A$ and $B$ adopts one of the two different roles in the equilibrium for strategic infrastructure investments. Further, the distinction between one or several innovative firms from the same country competing for a given patent allows us to study the qualitative impact of differences in industrial policy/sector structures in $A$ and $B$ for the countries’ choices of roles at the investment stage. A country may regulate its industry structure to avoid research duplication among home firms and may allow mergers that lead to national champions. Such a firm structure will be an advantage for this country in the stage-1 struggle with the other country about which country has the better chance of acquiring the more attractive role and the better position for an innovation competition among firms.

3 Equilibrium analysis

We first solve for the equilibrium of the subgame consisting of stages 2 and 3.

3.1 Stage 3: Exports to the RoW

A firm located in $I \in \{A, B\}$ that owns and exploits a patent for good $i$ chooses to produce a quantity $x^I_i$ of this good and export it to the rest of the world. Given (3) it obtains the monopoly profit $(2g_I - x^I_i)x^I_i$. This makes
use of zero unit production costs. From the first-order condition

$$\frac{\partial((2g_I - x_I^i)x_I^i)}{\partial x_I^i} = -2x_I^i + 2g_I = 0$$  \hspace{1cm} (4)$$

the monopoly quantity is $x_I^i = g_I$. Inserting the monopoly quantity into $(2g_I - x_I^i)x_I^i$ yields the monopoly profit as $r_I^i = (g_I)^2$.

The same logic applies for each of the patents owned by the $m_A$ and $m_B$ established firms and for firms with newly gained patents in stage 2. As all products have the same zero production cost and price response functions, the profit is the same for all products with patents in country $I$. While this is not a crucial assumption, it saves on notation and simplifies algebra.\(^6\)

### 3.2 Stage 2: Patent races

For each possible new patent $i \in \{1, ..., n\}$, there are firms from the non-empty sets $F_A^i$ and $F_B^i$ of firms that compete for this patent. We denote the number of firms in each of these sets as $\#F_A^i$ and $\#F_B^i$. The value of winning the race for patent $i$ is the monopoly rent that results in the market subgame in stage 3. Each of the $n$ races can be considered independently, irrespective of whether firms that compete for a patent $i$ own pre-existing patents, and how many other patents a firm is also competing for. For ease of notation let us drop the superscript $i$ and recall the definitions $r_A = (g_A)^2$ and $r_B = (g_B)^2$ such that $r_A$ and $r_B$ is both a measure of investment and the size of the resulting monopoly profit for each patent monopoly. Given the one-to-one correspondence between the government’s investment and firm profit, the investment choice is actually a choice of firm profits.

To solve for the firms’ patent effort choices we describe the patent races as static auctions\(^7\) and make use of the existing results on the equilibrium in all-pay auctions without noise, following examples in the literature such as Clark and Konrad (2008) and Fu, Lu, and Lu (2012). Equilibria of all-pay auctions without noise are typically in mixed strategies, and properties

\(^6\)We could, at the cost of more notation, generalize the analysis of this market stage and take $r_A^i$ and $r_B^i$ as product-specific functions of $g_A$, and $g_B$.

\(^7\)Dynamic innovation models can be represented equivalently by simple static all-pay auctions (cf. e.g., Baye and Hoppe, 2003).
of such equilibria were first derived by Hillman and Riley (1989) and then completely characterized in Baye, Kovenock, and de Vries (1996).

There are $n$ parallel patent races, and this makes it sufficient to describe equilibrium behavior in one of them. Equilibrium behavior depends on how many firms from each country might enter into the specific race, and on the previous government investment choices. We need to distinguish three cases.

Case 1: One competitor firm from each country  Suppose there are only two firms that are taking part in the all-pay contest for the patent for good $i$, one from each country (i.e., $\#F^i_A = 1$ and $\#F^i_B = 1$). Let these firms be denoted by $f_A$ and $f_B$. By the nature of monopoly behavior of the winner in stage 3, firm $f_A$ values winning the patent by $r_A$ and firm $f_B$'s valuation of winning is $r_B$. They choose efforts $e_{fA} \in [0, \infty)$ and $e_{fB} \in [0, \infty)$. We take note of the well-known result that an equilibrium in pure strategies in this type of all-pay contest does not exist.\(^8\) We characterize the existence and uniqueness of an equilibrium in mixed strategies, where the set of mixed strategies is given by the set of cumulative probability distribution functions (CDFs) denoted by $Y_A(e)$ and $Y_B(e)$:

**Lemma 1** (Baye et al. 1996, Theorem 3): If $\#F^i_A = \#F^i_B = 1$ then there is a unique subgame equilibrium in mixed strategies of patent contest efforts, described by CDFs $Y_A(e)$ and $Y_B(e)$ with common support $[0, \min\{r_A, r_B\}]$ and expected payoff $\max\{r_A, r_B\} - \min\{r_A, r_B\}$ to the firm from the country that has chosen the higher investment amount and in expectation zero payoff to the other firm.

**Proof.** Anticipating the monopoly-subgame equilibrium at stage 3, the patent race for $i$ is an all-pay auction with two competing firms as bidders

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\(^8\)To illustrate, suppose otherwise. Suppose $(e_{fA}^i, e_{fB}^i)$ is a pure strategy equilibrium in the contest for patent $i$. Suppose, by appropriate labelling that $r_A \geq r_B$. Then both $e_{fA}^i \leq r_B$ and $e_{fB}^i \leq r_B$. If $e_{fA}^i = e_{fB}^i \in [0, r_B)$, then $f_A$ can improve its payoff by a marginally larger $e_{fA}^i$. If $e_{fA}^i = e_{fB}^i = r_B$, then $f_B$ can increase its payoff by choosing $e_{fA}^i = 0$. For $e_{fA}^i < e_{fB}^i$ then $f_B$ can increase its payoff by a slightly smaller $e_{fB}^i$. For $e_{fA}^i > e_{fB}^i > 0$, this is not optimal for $f_B$ and $f_B$ can increase its payoff by choosing $e_{fB}^i = 0$. But for $e_{fA}^i > e_{fB}^i = 0$ firm $f_A$ can increase its profit with a small reduction in $e_{fA}^i$. 

12
and valuations of winning of $r_A = (g_A)^2$ and $r_B = (g_B)^2$. The Lemma 1 then follows directly from Theorem 3 in Baye et al. (1996).

Seen from a strategic trade perspective, this result is also intuitive, as differences in the infrastructure level have the flavor of differences in the production costs, known from the generic strategic trade model. However, the mechanism that translates differences in trade infrastructure quality levels into firms’ expected payoffs is somewhat different and more indirect than an R&D subsidy. The firm with the lowest trade costs gains more from winning the monopoly. Hence, it is more eager to win the patent race, and this is an advantage in the all-pay contest. This advantage translates into more effort in expectation, a higher equilibrium win probability and a positive expected payoff. The other firm receives a zero expected payoff, in line with insights from the all-pay auction literature.

A closer look at the equilibrium characterization in Theorem 3 in Baye et al. (1996) reveals the deeper logic: For $r_A \geq r_B$, the equilibrium mixed strategies are characterized by cumulative distribution functions

$$Y^i_A(e^i_A) = \frac{e^i_A}{r_B}$$

(5)

and

$$Y^i_B(e^i_B) = (1 - \frac{r_B}{r_A}) + \frac{e^i_B}{r_A}$$

(6)
on the common support $[0, r_B]$. It is easy to confirm that these strategies make the firms mutually indifferent toward which effort levels from the support $(0, r_B)$ to choose. The expected payoffs emerging from choices from the interval $(0, r_B)$ give $f_A$ an expected payoff of $r_A - r_B$ and $f_B$ an expected payoff of zero. For $r_B > r_A$ the subscripts $A$ and $B$ would have to be exchanged but the results apply analogously. For $r_A > r_B$ and the equilibrium strategies (5) and (6) the product $i$ is innovated in country $A$ with probability

$$q^i_{f_A} = (1 - \frac{r_B}{r_A}) + \frac{1}{2} \frac{r_B}{r_A} = \frac{2r_A - r_B}{2r_A} > \frac{1}{2},$$

(7)

and in country $B$ with probability $1 - q^i_{f_A}$. This means that the firm in the country with the lower infrastructure investment (= higher trade costs) can also win, but with some probability smaller $\frac{1}{2}$. In expectation the firm in
the country with the lower international trade infrastructure expends lower contest resources and wins with a lower probability.

Let \( n_{11} \) denote the number of patent races in which one firm from each country is competing with one firm from the other country \( (i.e., \text{for which } F^i_A = F^i_B = 1) \). As the patent races are independent from each other, the expected payoffs of the countries from the \( n_{11} \) patent contests are the product of expected payoff from each single such patent race and \( n_{11} \). In the case \( r_A > r_B \) country \( A \)'s expected payoff from these \( n_{11} \) innovation competitions is \( (r_A - r_B)n_{11} \) and zero for \( B \).

**Case 2: One competitor in one country, multiple competitors in the other** Let us turn to a patent race for a new good \( i \) in which one country has more than one firm competing for the patent and the other country has only one firm that is ready to enter into this race, for instance, let \( F^i_A = 1 \) and \( F^i_B > 1 \). The prize for a firm that wins the patent is \( r_A \) if the firm is located in \( A \) and is \( r_B \) if the winning firm is located in \( B \). Who the active bidders are in the situation \( F^i_A = 1 \) and \( F^i_B > 1 \), what effort choices they make and what expected payoffs they have depends on \( r_A \) and \( r_B \), i.e., on the valuations of winning for firms from country \( A \) and from country \( B \):

**Lemma 2** (Baye et al., 1996, Theorem 1 and Theorem 2): Let \( F^i_A = 1 \) and \( F^i_B > 1 \). (i) If \( r_A > r_B \), then there is a multiplicity of subgame equilibria, but all subgame equilibria have the same expected subgame payoffs for the firms, such that the payoff of \( f_A \in F^i_A \) is \( r_A - r_B \) and that of all firms in \( F^i_B \) is zero. (ii) If \( r_A \leq r_B \), then there is a unique equilibrium only if \( r_A < r_B \) and \( F^i_B = 2 \). Otherwise there is a multiplicity of subgame equilibria. In all these cases all firms’ expected payoffs are zero in equilibrium.

**Proof.** Anticipating the monopoly-subgame equilibrium in stage 3, the patent race is equivalent to an all-pay auction without noise for a prize \( r_A \) for one player \( (\text{the one in } F^i_A) \) and of \( r_B \) for the players from \( F^i_B \). The rest of Lemma 2 follows straightforwardly as special cases from Theorem 2 \( (\text{for } r_A > r_B) \) and Theorem 1 \( (\text{for } r_A \leq r_B) \) in Baye et al. (1996). □

The lemma shows that a positive rent emerges only if at least one country has a single competing firm, and if this country is the one for which the
firm’s monopoly rent of winning is higher than that for other firms. The case clearly illustrates how a ‘national champion’ industry structure can benefit the country with this structure. The result illustrates the key role of the relative size of governments’ infrastructure investments, and of the industry structure in the countries. With a coordinated or concentrated industry structure in one country, such that there is no internal competition for winning the patent, this helps to avoid firms from the same country competing with each other and dissipating the winning prize in the patent race. If this is also the country with the higher infrastructure investment, then that country gains positive benefits of the innovation conflict. The expected innovation rent goes to this country. For the country that has multiple similar firms that are competing with each other among themselves, even if this country made the highest infrastructure investments, the firms inside the country compete and dissipate the rent from winning.9 This logic, in turn, will be important when considering the countries’ incentives to invest in infrastructure. Such investments are more attractive for the country that has national champions for many of the goods that can be innovated.10

Case 3: Multiple competitors in both countries The final case is when both countries have more than one home firm that competes for the patent (i.e., \( #F_A^i > 1 \) and \( #F_B^i > 1 \)).

**Lemma 3** (Baye et al., 1996, Theorem 1): Let \( #F_A^i > 1 \) and \( #F_B^i > 1 \). All all-pay auction equilibria for patent \( i \) have zero expected payoffs for all firms. (i) If \( r_A > r_B \), then only firms in \( A \) choose positive efforts and the patent goes to one of the firms in \( A \). (ii) If \( r_A < r_B \), then only firms in \( B \) choose positive efforts and the patent goes to a firm in country \( B \). (iii) If

---

9Considering homogeneous trade costs keeps the analysis simple and allows us to focus on the effect of trade-cost differences. It is intuitively straightforward how the analysis is modified if firms with different genuine unit costs of innovation effort are considered. In this case the single firm’s comparative advantage in the all-pay auction is jointly determined by genuine differences in innovation costs and trade cost differences.

10Note finally that a ‘national champion’ for a given patent race is not defined here as one with lower costs or higher abilities than other firms in the country, but is defined by the absence of a competing, similarly strong firm from within the same country.
$r_A = r_B$, then firms from $A$, from $B$ or from both countries might choose positive efforts in equilibrium and the patent might go to a firm in $A$ or $B$.

**Proof.** There are $\#F^i_A + \#F^i_B$ firms competing for the patent. In all cases there are at least two firms with the highest valuation of winning. Theorem 1 in Baye et al. (1996) applies. Firms’ valuations of winning the patent are $r_A$ and $r_B$, respectively. If all firms with the same highest value of winning are from the same country, only these firms expend positive efforts and the patent goes to one of them. If the highest-value firms are from both countries, then this is an all-pay auction between $(\#F^i_A) + (\#F^i_B)$ symmetric players. In all cases the equilibrium expected payoffs of all firms are zero. ■

Lemma 3 describes the all-pay-auction equilibrium if both countries host two or more firms that have the same valuation of winning the auction for patent $i$. One type of equilibrium has mixed strategies for two of the players with mixed strategies as in (5) and (6) but for the case in which several players have the same highest prize valuation. As Baye et al. (1996) show, if the number of such players is larger than two, then there are also further equilibria, including a symmetric equilibrium in which all these players have the same mixed strategy. But in all these equilibria the value of winning the patent is fully dissipated in expectation. Firms’ expected payoff is zero.

Patents that are that heavily contested do not provide an incentive for the governments to increase their investment levels: if a country has a higher investment level than the other country, this will lead to one of the firms in this country winning the patent and earning the monopoly rent. However, the strong competition among the firms from the inside of this country induce patent-race efforts that dissipate this monopoly benefit in expectation.

**Overview of stage 2** Summarizing the three cases and results in Lemma 1 to Lemma 3, the sum of expected surpluses generated in the patent race for patent $i$ can be positive or zero, and is precisely determined by $r_A$, $r_B$ and by the sizes of the sets of firms $F^i_A$ and $F^i_B$. Only if there is one single firm from the country that has the lowest trade cost, then is there a positive expected payoff from the patent race and the subsequent monopoly game for this firm. This positive expected payoff equals the difference between this single firm’s valuation of winning and the second-largest valuation of winning.
By construction of the set-up, this difference is \( \max\{r_A, r_B\} - \min\{r_A, r_B\} \).

If there are several firms that value winning the patent most highly and value it equally, then the competition between them is very fierce. While there might be several equilibria that differ in which firms make active bids and how the mixed strategies look, in each of them the sum of expected efforts equals the common valuation of winning.

Recall that there are \( n \) patent races, one for each of these new goods \( i \). These contests occur in parallel and independently of each other. The \( r_A \) and \( r_B \) are the same in all these patent races, but the composition of firms that choose efforts in the respective patent races may differ for different goods \( i \).

Let the number of patent competitions for which

\[
\begin{align*}
\#F_A^i = \#F_B^i &= 1 & \text{be } n_{11} \\
\#F_A^i = 1 \text{ and } \#F_B^i > 1 & \text{ be } n_{1k} \\
\#F_A^i > 1 \text{ and } \#F_B^i = 1 & \text{ be } n_{k1} \\
\#F_A^i > 1 \text{ and } \#F_B^i > 1 & \text{ be } n - n_{11} - n_{1k} - n_{k1}
\end{align*}
\] (8)

Then, as an implication of the three lemmas, the sum of all firms’ expected payoffs are

\[
\begin{align*}
(n_{11} + n_{1k})[\max\{(r_A - r_B), 0\}] + m_A r_A \text{ in country } A \\
(n_{11} + n_{k1})[\max\{(r_B - r_A), 0\}] + m_B r_B \text{ in country } B.
\end{align*}
\] (9)

Equipped with these results on the expected firm profits that accrue in the subgame with stages 2 and 3 we can now approach the stage in which the countries choose their strategic trade-cost-reducing investments.

### 3.3 Stage 1: trade-cost-reducing investments

Consider the objective function of country \( A \) in stage 1, assuming subgame perfect equilibrium play in stages 2 and 3. Recall the definitions (8) of \( n_{11}, n_{1k}, n_{k1} \) and that \( n_{11} \geq 1 \). Given the size of the monopoly profits \( r_A \) and \( r_B \) of patent holders we can write \( A \)’s objective function

\[
W_A = m_A r_A + (n_{11} + n_{1k})[\max\{(r_A - r_B), 0\}] - c(r_A).
\] (10)

The first term describes the monopoly profits from pre-existing patent monopolies owned by firms in \( A \). The last term accounts for the government’s
investment cost. The middle term is the sum of expected net innovation rents of firms in $A$ from the patent races in stage 2. As shown by Lemma 1 to Lemma 3, a positive net surplus from taking part in the innovation races does not emerge in $A$ if $r_A \leq r_B$. If the monopoly rent of a patent winning firm from $A$ falls short of the rent of a winning firm in $B$, then the all-pay auction payoff for this patent race is zero for firms in $A$. Similarly, if multiple firms with the highest patent monopoly value are located in $A$, one of them might win the patent, but the firms expend patent race effort that, in expectation, equals the firm’s win probability times the firm’s valuation of winning the patent.\footnote{The symmetry assumptions of firms from the same country facilitate the analysis here. If there are stronger and weaker firms in the same country that are competing with each other, their competition does not necessarily dissipate the monopoly rent that the stronger firm can win. Also, the strength of a firm might overcompensate the weak infrastructure that its country provides. The symmetry assumption is made to highlight and concentrate on the relationship between countries’ investments and firms’ innovation rents.} The monopoly rents $r_A$ and $r_B$ are continuous and are strictly monotonic functions of $g_A$ and $g_B$. This allows us to state the strategies and the objective function of country $A$ in (10) in terms of $r_A$. Analogously, the objective function for country $B$ is

$$W_B = m_B r_B + (n_{11} + n_{1k}) \max\{(r_B - r_A), 0\} - c(r_B).$$  

We define three critical investment values. First, let us define $r^s_A$ as the solution of

$$m_A = c'(r_A)$$

and call this the stand-alone investment choice of $A$. Note that such a solution exists and is unique, as $m_A$ is a positive constant, $c'(0) = 0$, and $c'(r_A)$ is convex and grows to values higher than $m_A$ for a large $r_A$. Note also that $r^s_A$ is independent of $r_B$. Analogously, we define the stand-alone solution $r^s_B$ as the solution of $m_B = c'(r_B)$. Note that $A$’s stand-alone solution is larger than that of $B$’s if, and only if, $m_A > m_B$, i.e., if $A$ has the larger pre-existing export sector, measured by the number of pre-existing patents.

Second, we define $r^h_A$ as the solution of

$$m_A + (n_{11} + n_{1k}) = c'(r_A).$$
Figure 1: Country A’s payoffs of the candidate equilibrium investment choices as functions of the other country’s investments. The figure defines the three critical investment levels.

The solution of (13) also exists and is unique under the properties of $c(r)$. We call this investment level the hegemonic investment level for A. Condition (13) determines the value $r_A$ such that a marginal increase in $r_A$ causes a marginal increase in the expected export profits that equals the marginal cost. Note that $r_A^* < r_A^h$ as $n_{11} + n_{1k} \geq 1$. Further, $r_A^*$ is the choice that maximizes country A’s welfare for all $r_A < r_B$ if $r_B \geq r_A^*$. Similarly, $r_A^h$ maximizes A’s welfare for all $r_A > r_B$ if $r_B < r_A^h$.

Figure 1 draws the payoff of country A as a function of $r_B$ if A chooses $r_A^*$.  

\[
W_A^*(r_B) = m_A r_A^* + (n_{11} + n_{1k}) \max\{(r_A^* - r_B), 0\} - c(r_A^*)
\]  

in red (solid line). Similarly, the blue (dashed) function is  

\[
W_A^h(r_B) = m_A r_A^h + (n_{11} + n_{1k}) \max\{(r_A^h - r_B), 0\} - c(r_A^h).
\]  

It describes country A’s expected payoff as a function of $r_B$ if A chooses the hegemonic investment level $r_A^h$. 

Electronic copy available at: https://ssrn.com/abstract=4624499
Note that it follows from the marginal conditions that define \( r_A^* \) and \( r_A^h \) and \( n_{11} + n_{1k} \geq 1 \) that, for \( r_B = 0 \), we have
\[
W_A^s(0) = m_A r_A^s + (n_{11} + n_{1k}) r_A^s - c(r_A^s) \quad (16)
\]
\[
< m_A r_A^h + (n_{11} + n_{1k}) r_A^h - c(r_A^h) = W_A^h(0). \quad (17)
\]
Both functions \( W_A^s(r_B) \) and \( W_A^h(r_B) \) are continuous, have the same negative slope \(-(n_{11} + n_{1k})\) for \( r_B < r_A^s \) and \( r_B < r_A^h \), and become constant for \( r_B > r_A^s \) and \( r_B > r_A^h \) at payoff levels \( m_A r_A^s - c(r_A^s) \) and \( m_A r_A^h - c(r_A^h) \). As \( r_A^s \) maximizes \( m_A r_A - c(r_A) \) it also holds that \( m_A r_A^h - c(r_A^h) < m_A r_A^s - c(r_A^s) \). This implies that the functions \( W_A^s(r_B) \) and \( W_A^h(r_B) \) intersect exactly once. This intersection identifies the investment level \( r_B \) of the other country \( B \) which makes \( A \) just indifferent between choosing \( r_A^s \) or \( r_A^h \), and we define this critical level as \( r_B = \alpha \). For \( r_B < \alpha \) country \( A \) prefers \( r_A^h \) to \( r_A^s \), for \( r_B > \alpha \) country \( A \) prefers \( r_A^s \) to \( r_A^h \).

Note that a hegemonic investment level for country \( B \) is defined analogously and is denoted by \( r_B^h \), and similar considerations apply for \( r_B^h \). Corresponding to the definition of \( r_B = \alpha \), analogous considerations determine one critical level of \( r_A \) that makes \( B \) indifferent between \( r_B^s \) and \( r_B^h \) and we define this critical level as \( r_A = \beta \).

With these considerations and definitions in mind, we state:

**Proposition 1** If an SPE in pure investment strategies exists it must be an element of the set \( \{(r_A^h, r_B^h), (r_A^s, r_B^s)\} \).

**Proof.** In any pure strategy equilibrium \((r_A^*, r_B^*)\) either \( r_A^* < r_B^* \), \( r_A^* = r_B^* \) or \( r_A^* > r_B^* \).

Assume that a pure-strategy equilibrium with \( r_A^* < r_B^* \) exists. Then \( r_A^* \) must maximize \( W_A \) as in (10) on the interval \([0, r_B^*] \). Note that \( m_A r_A - c(r_A) \) is strictly monotonically increasing for \( r_A < r_A^* \) and strictly monotonically decreasing for \( r_A > r_A^* \). Together with strict inequality \( r_A^* < r_B^* \) the optimality of \( r_A^* \) on the interval \([0, r_B^*] \) implies that \( r_A^* = r_A^s \). For similar reasons, \( r_B^* \) must maximize \( W_B \) on the interval \((r_A^s, \infty) \). Note that \( m_B r_B + (n_{11} + n_{1k})(r_B - r_A^s) \) is strictly monotonically increasing for \( r_B < r_B^* \) and strictly monotonically decreasing for \( r_B > r_B^* \). Together with strict inequality \( r_A^* < r_B^* \), optimality on the interval \([r_A^s, \infty) \) implies \( r_B^* = r_B^h \). Hence, if the equilibrium has \( r_A^* < r_B^* \), then it must be that \((r_A^*, r_B^*) = (r_A^s, r_B^h)\).
For analogous reasons, the existence of a pure-strategy equilibrium with \( r_A^* > r_B^* \) implies that, if it exists, then \( (r_A^*, r_B^*) = (r_A^h, r_B^s) \).

Finally, we consider the possibility that \( r_A = r_B = r^* \) in equilibrium. We show that this cannot be a pure-strategy equilibrium. Suppose first that \( r_A^* = r_B^* = r^* > r_A^h \). Then, a marginally smaller \( r_A \) gives \( A \) higher welfare, as
\[
\frac{\partial}{\partial r}(m_A - c'(r)) < 0
\]
at \( r_A = r_B = r^* > r_A^h \). This contradicts the optimality of \( r_A = r^* \). Suppose next \( r_A^* = r_B^* = r^* < r_A^h \). Then, a marginally larger \( r_A \) increases \( A \)'s welfare, as for \( r^* < r_A^h \), it holds that, by the definition of the stand-alone investment,
\[
\frac{\partial}{\partial r}(m_A - c'(r)) > 0
\]
at \( r_A = r_B = r^* < r_A^h \). The same reasoning applies symmetrically for \( B \) and rules out \( r^* < r_B^h \) and \( r^* > r_B^s \). Hence, the only remaining combination to consider is \( r^* = r_A^s = r_B^s \). It then holds that a marginal increase in \( r_B \) at \( r^* = r_A^s = r_B^s \) yields a change in \( B \)'s payoff by
\[
\lim_{r_B \downarrow r_B^s} \left( \frac{\partial W_B}{\partial r_B} \right) = m_B + n_{i1} + n_{k1} - c'(r_B) > 0.
\]
This is a contradiction and completes the proof.

Proposition 1 establishes that the set of pure strategy equilibria that might exist has only two candidate equilibria. Implicitly it also establishes that only the stand-alone quantities and the hegemonic investment quantities can be equilibrium choices in a pure-strategy equilibrium.

In each of the equilibrium candidates in Proposition 1 the two countries take asymmetric roles. One country accommodates a role in which it basically ignores the possible innovation contests. Some of the country’s firms take part in some of these patent races, but given their country’s low stand-alone investment, they will not have positive expected payoffs from this activity. The existence of these innovation contests does not give the country an incentive to increase its investment at the margin. So, if country \( A \) chooses the stand-alone role it invests as if there is only the old existing export industry with its \( m_A \) pre-existing patents.
The alternative candidate behavior of a country is to make its own firms competition-ready for the patent races such that they benefit from these races in expectation. This will imply a high investment level, and exactly this anticipated aggressive behavior is sufficient to deter the other country from high investments.

The proposition opens up for four possibilities: none of the elements of \{(r_A^h, r_B^h), (r_A^s, r_B^h)\} is an SPE, both of these are equilibria, or one of them is an SPE and the other is not. The purpose of the remainder of this sub-section is to characterize conditions for these cases, and to confront them with the stylized empirical findings on China’s high existing export sector, China’s industrial policy, and China’s comparatively high trade-facilitating investments.

**Proposition 2**

(i) \((r_A^h, r_B^h)\) is an SPE if \(r_B^s < \alpha\) and \(r_A^h > \beta\).

(ii) \((r_A^s, r_B^h)\) is an SPE if \(r_A^s < \beta\) and \(r_A^h > \alpha\).

**Proof.** It is sufficient to prove one of these claims. We prove (i). By the definition of \(\alpha\), (10) takes a maximum on the interval of possible choices \(r_A \in [0, \infty)\) at \(r_A = r_A^h\) if \(r_B < \alpha\). Hence, \(r_A^h\) is an optimal reply to \(r_B^s\) if \(r_B^s < \alpha\). Furthermore, according to the definition of \(\beta\), (11) takes a maximum on the interval of possible choices \(r_B \in [0, \infty)\) at \(r_B = r_B^h\) if \(r_A > \beta\). Hence, \(r_B^h\) is an optimal reply to \(r_A^h\) if \(r_A^h > \beta\). This shows that \((r_A^h, r_B^h)\) are mutually optimal replies. ■

The condition \(r_B^s < \alpha\) makes \(W_A^h(r_B^s) > W_A^s(r_B^s)\). So, if B chooses \(r_B^s\), then the hegemonic investment choice \(r_A^h\) is an optimal reply. Similarly, \(r_A^h > \beta\) makes \(W_B^s(r_A^h) > W_B^h(r_A^h)\). Therefore, should A choose \(r_A^h > \beta\), then \(r_B^s\) is B’s optimal reply. Intuitively, these conditions make sure that the stand-alone choice of B is sufficiently small such that A’s benefit from topping B’s stand-alone investment level and going for the hegemonic investment level is optimal: \((r_A^h - r_B^s)\) and the benefits that emerge on pre-existing monopolies and on the expected innovation rents of A’s firms is sufficiently large to overcompensate the higher cost \(c(r_A^h) - c(r_A^s)\) for country A. And at the same time, this hegemonic investment is sufficiently high such that B would not like to top it. Rather, B’s optimal reply becomes the stand-alone investment.

22
Proposition 3 Let the countries be symmetric (i.e., $m_A = m_B$ and $n_{11} + n_{1k} = n_{11} + n_{k1}$). Both SPEs $(r_A, r_B) = (r_A^h, r_B^h)$ and $(r_A, r_B) = (r_A^s, r_B^h)$ exist.

Proof. If the countries are symmetric, then it is evident that $r_A^s = r_B^s < \alpha = \beta < r_A^h = r_B^h$. Accordingly, the conditions in the previous proposition are fulfilled, and by symmetry for both equilibrium candidates.

The following observations might be worthwhile. First, the assumptions (A1) and (A2) are binding. If $n = 0$ such that there are no new patents to compete for, then both countries simply go for their stand-alone solutions. Then, $r_A^s = r_A^h$ and $r_B^s = r_B^h$. Second, if there are no patent competitions for which the all-pay contest generates an expected rent for a firm in the country with the higher investment level (i.e., if $n_{11} + n_{1k} = 0$ and $n_{11} + n_{k1} = 0$), then the patent races are irrelevant for the incentives of the country governments. Again, $r_A^s = r_A^h$ and $r_B^s = r_B^h$. Assumption (A2) is a sufficient condition for such patent rents to exist if the countries choose different investment levels. Third, it is clear by continuity that the result in Proposition 3 on symmetry extends to countries that are sufficiently similar in terms of pre-existing patents and in terms of $n_{1k}$ and $n_{k1}$.

For sufficiently symmetric countries, the existence of two asymmetric equilibria suggests that the stand-alone role and the hegemonic role are not clearly assigned to one or the other country. For equilibrium, the countries need to coordinate. In the Appendix we illustrate that, for perfect symmetry, a symmetric equilibrium without coordination exists, but has mixed strategies.

Next, we note that one of the asymmetric equilibria vanishes if the asymmetry in pre-existing export sectors or in their industry structure is sufficiently large. The next proposition describes a sufficient condition for when only one equilibrium remains.

Proposition 4 Take the symmetric situation with $m_A = m_B = m$ and $n_{1k} = n_{k1}$ in which both SPEs $(r_A^h, r_B^h)$ and $(r_A^s, r_B^h)$ exist. (i) The equilibrium $(r_A^h, r_B^h)$ ceases to exist if $m_B$ becomes sufficiently large. (ii) The equilibrium $(r_A^s, r_B^h)$ can also cease to exist if $n_{k1}$ becomes sufficiently large.
**Proof.** Consider Figure 1 and start with perfect symmetry, such that \( W^s_A(r) = W^s_B(r) = W^h_A(r) = W^h_B(r) \). Let \( \alpha = \beta \) be determined by \( W^s(\alpha) = W^h(\alpha) \).

(i) An increase in \( m_B \) does not change \( r^s_A \), \( r^h_A \) or \( \alpha \). However, an increase in \( m_B \) causes both \( r^s_B \) and \( r^h_B \) to increase. Starting from symmetry, replace \( m_B \) by \( \hat{m}_B > m_B \) sufficiently such that \( B \)'s stand-alone investment \( \hat{r}^s_B > \alpha \). In this case the optimal reply of \( A \) to \( \hat{r}^s_B \) is no longer \( r^h_A \), in contradiction to the hypothesis that the equilibrium \( (r^s_A, r^h_B) = (r^h_A, r^s_B) \) exists. This shows that a sufficiently large asymmetry in the pre-existing export sectors determines that the country with the larger export sector takes on the hegemonic role.

(ii) Starting from symmetry, a change in \( n_{k1} \) to \( \hat{n}_{k1} > n_{k1} \) has several implications. First, \( W^s_A \) and \( W^h_A \) remain unchanged. Second, \( r^s_B \) and \( W^s_B \) remain unchanged. The optimal hegemonic investment of country \( B \) increases to \( \hat{r}^h_B \). Furthermore, \( W^h_B \) changes to \( \hat{W}^h_B \) which has a higher intercept and becomes steeper: the new slope is \( -m_B - n_{11} - \hat{n}_{k1} \). These changes determine a new point of intersection of \( W^s_B \) and \( \hat{W}^h_B \) at \( \hat{\beta} \). If \( \hat{\beta} > r^h_A \), then \( r^s_B \) is no longer an optimal reply to \( r^h_A \), such that \( (r^h_A, r^s_B) \) is no longer an SPE.

Intuitively, there are two motives that induce countries to make trade-cost-reducing investments. First, such investments help their own established export industries. Second, the country with higher investments earns some innovation rents, and these are higher for country \( A \) than for country \( B \) if \( n_{1k} > n_{k1} \). If the first investment motive is much stronger for one of the countries (e.g., \( m_A >> m_B \)), then, ignoring the second motive, country \( A \) chooses a much higher investment than \( B \). But in order to benefit from innovation rents, country \( B \) would have to invest absolutely more than \( A \)'s stand-alone investment level. And the perspective of possible innovation rents might simply not be large enough for the country with the smaller pre-existing export sector to make this a worthwhile choice.

This consideration has an important policy implication. If the export sector of one country is much larger than the other, then only the equilibrium might exist in which this country takes the hegemonic role. A similar logic applies if one country has the advantage in terms of industrial structure with national champions. For instance, if \( n_{1k} \) is much larger than \( n_{k1} \) it becomes...
gradually more natural for the hegemonic role to be taken by country A with the stand-alone role being taken by country B. If country A has a very large $m_A$ and, at the same time, $n_{k1}$ is very large, then the first effect is an advantage for A and the second effect is an advantage for B, and the two effects could counteract each other. But as suggested by the stylized facts that are mentioned in the introduction, China has both advantages: it has a larger pre-existing export sector and it works on an industry structure that aims at national champions.

4 Policy implications, empirical predictions, and conclusions

The theory unfolded in this paper attempts to explain a set of stylized facts in the introduction with a unified theory of international infrastructure investments and innovation incentives. The stylized facts are: (i) the government of China strongly invests in infrastructure to improve trade links between China and its export markets. (ii) Such investments facilitate trade, and can thereby increase China’s payoffs from exports. (iii) China and the US have export sectors of different sizes. China’s existing export sector is almost twice the size of the US in terms of sales. (iv) Both nations’ firms are participating in innovation races. (v) The innovation activities of companies are governed by different industrial policies in the two economies. China leans to a policy of concentrated industry sectors with national champions and the government intervenes in the context of R&D.

The theoretical analysis of this nexus brings these five stylized facts into a coherent context. Trade-cost-reducing investments aim at enabling greater profits for domestic firms in exports. At the same time, the investments have a strategic component. Higher export profits give national innovative firms a greater incentive to undertake innovation efforts for new products that can be exported. In doing so, innovative firms compete with other domestic innovative firms, but also with the same type of firms in the other competitor nation. The innovation stimulus that country A’s investments causes on companies in country A therefore has indirect, “strategic” effects on inno-
ivation activities of firms in the other country. This strategic competition
does not lead to a symmetric “race” with a symmetric general increase in
infrastructure investments among the two countries. It typically has asym-
metric equilibria in which one of the countries invests more and wins the
greater innovation rent. Role-assignment is not random, however. A key
result of the theoretical analysis is: a larger existing export sector is a main
reason for that country being in the role of winning the larger number of
innovation rents. Applied to the US-China conflict, this key result which is
clearly implied by Proposition 4, is perhaps the most relevant result of the
analysis.

A similar logic applies to differences in the internal competition structure
of innovative firms in the respective country. For the question of which
country receives the innovation rents in equilibrium, it is advantageous for a
country if the innovation efforts of the companies at home are coordinated
and domestic competition among its own companies is reduced or prevented
by a national-champions policy and a tight and ‘hands-on’ governmental
industrial policy.

Given the stylized facts about export sector size and industrial policies,
there is reason to believe that these factors currently work in favor of China.

The considerations here can also be seen in the broader context of geostrate-
gic competition between China and the USA. The conflict between China
and the US is well recognized (e.g., Layne, 2018), and governmental trade-
infrastructure investment as well as innovation competition are important
elements of this conflict. The USA was the real victor from World War II
and has emerged economically and militarily strengthened from the Cold War
competition with the Soviet Union as the only hegemonic power on earth.
This unipolar system (Waltz, 2000) has survived 40 years in the meantime.
Strategic thinkers such as former US Secretary of State Zbigniew Brzezinski
(1997, 2012) have reflected on whether and how the United States might
succeed in defending its hegemonic position. Military clout is an important
factor in the relative positioning of the United States and China to each other
(Posen, 2003, and Layne, 2006). An arms race between the two great powers
might emerge and political-military conflict might result (Allison, 2017, and
Mearsheimer, 2014). However, the ability to accumulate large stocks of war

26
ships, missiles, and other types of weapons is ultimately a function of relative economic and technological strength. Technological strength thus moves to the center of geostrategic considerations.

Theoretical foundations for such a consideration lie in the development of the theory for which Luttwak (1990) has termed geoeconomics, that is, the pursuit of national interests in the international sphere not by traditional means of diplomacy or by military means, but through the use of instruments that belong in the realm of international economics. The work here highlights the role of trade-cost-reducing investments, the role of the existing size of export sectors, and the role of differences in the type of national innovation policies for the question of which country is more likely to win the innovation competition. The outcome of this competition might then ultimately translate into hegemonic economic and military power.

4.1 Appendix

Non-coordinated symmetric equilibrium Consider the SPEs for \( m_A = m_B = m > 0 \) and for \( \#F^i_A = \#F^i_B = 1 \) for all \( i = 1, \ldots, n \). Countries’ payoffs are asymmetric in each of the two asymmetric pure-strategy SPEs that exist. Country A prefers \((r^h_A, r^s_B)\) and country B prefers \((r^s_A, r^h_B)\). So, how do they coordinate on one of the two equilibria? In the absence of a reason as to why the governments of A and B should be able to coordinate on different roles, we might want to look for an uncoordinated and non-cooperative symmetric equilibrium.

Such an equilibrium can be characterized. We illustrate this for a particular parametric cost function, such that we can provide a closed form equilibrium solution: let the cost function be

\[
c(r) = \frac{1}{2} r^2
\]

i.e., quadratic in the size of the firms’ monopoly rents that the infrastructure choice generates.

**Proposition 5** A symmetric subgame perfect equilibrium exists in which the two countries randomize their choices \( r_A \) and \( r_B \) independently and uniformly
with cumulative distribution functions of their investment choices \( R_A(r) = R_B(r) = R(r) = \frac{r-m}{n} \) and support \( r \in [m, m+n] \).

**Proof.** A proof must show that the mixed strategies described by cumulative distribution functions \( R_A = R_B = R \) are mutually optimal replies. Let \( R_B(r) = \frac{r-m}{n} \) with support \( r \in [m, m+n] \). Then, as \( R'_B(r) = \frac{1}{n} \) on this support,

\[
W_A(r_A) = n \int_{m}^{r_A} \frac{1}{n} (r_A - \rho) d\rho + mr_A - \frac{1}{2} r_A^2 = \frac{1}{2} m^2
\]

for all \( r_A \in [m, m+n] \). Accordingly, \( R_B(r) = \frac{r-m}{n} \) gives \( A \) the same payoff for all \( r_A \in [m, m+n] \). Choices \( r_A < m \) gives \( A \) a payoff of \( mr_A - \frac{1}{2} r_A^2 \). It holds that, for \( r_A \in (0, m) \), \( \frac{\partial W_A(r_A)}{\partial r_A} = m - r_A > 0 \), such that \( mr_A - \frac{1}{2} r_A^2 < \frac{1}{2} m^2 \) in this range. Furthermore, for \( r_A > m + n \) it holds that \( R'_B(r_A) = 0 \), such that

\[
W_A(r_A) = n \int_{m}^{m+n} \frac{1}{n} (r_A - \rho) d\rho + mr_A - \frac{1}{2} r_A^2.
\]

Hence, \( \frac{\partial W_A(r_A)}{\partial r_A} = m + n - r_A < 0 \), such that the payoff falls short of \( \frac{1}{2} m^2 \) for \( r_A > n + m \). This shows that only \( r_A \in [m, n+m] \) are optimal replies to the candidate equilibrium mixed strategy by \( B \), and so is the mixed cumulative distribution function \( R_A(r) = \frac{r-m}{n} \) with support \( r \in [m, m+n] \). The same reasoning applies for country \( B \), and hence, these mixed strategies are mutually optimal replies. 

It is clear from this analysis how the consideration extends to a more general cost function \( c(r) \), but a characterization could typically not be given as a closed form solution. It is also clear from Proposition 4 that asymmetry between countries is a challenge for such mixed strategy equilibrium: for sufficient asymmetry a single pure-strategy equilibrium remains, and as this equilibrium is in pure strategies and is unique in pure strategies, it has a strong appeal.

The equilibrium that is described in Proposition 5 is seemingly reminiscent of the mixed strategy equilibria that emerge in the context of the all-pay auction (Hillman and Riley, 1989, Baye, Kovenock, and, de Vries 1996) or in the context of Bertrand competition with loyal customers (Varian, 1980, Narasimhan, 1988). However, a major difference becomes apparent: in the
all-pay auction a player attempts to outcompete another player. And whether
the winning player succeeds with a small or with a wide margin does not
matter for the winner’s payoff. An object goes to the bidder who made the
higher bid, and this player’s payoff is the value of the object minus the bid
that the player made. Similarly, in Bertrand games with loyal customers,
a firm attracts all non-loyal customers if it sets a price that undercuts the
price of the other player, by whatever margin. In the type of competition
here, the size of the gain of the winning country depends on the difference in
this country’s and the competing country’s infrastructure investment. If one
country invests more than the other, but only by a small epsilon amount,
then the winning country wins only something of the order of magnitude of
epsilon. So, the purpose is not to invest more than the other country, but
to win with a preferably wide margin. The value of winning is a direct and
increasing function of the size of this margin.

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