Technology, Geopolitics, and Trade[‡]

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Abstract

We study how geopolitical shocks reshape innovation through the contractual structure of cross-border technology adoption. Empirically, royalty flows are more sensitive than goods trade to geopolitical distance, especially where intellectual property enforcement is weak. We build a growth-trade model in which political risk raises breach hazards in licensing contracts. Firms reprice royalties but compliant adoption declines, and innovation incentives respond to the joint evolution of price and quantity. Quantitatively, fragmentation reallocates innovation and lowers the balanced-growth path growth rate. This mechanism has direct policy implications: under a consumption-only objective there is no role for export controls: Intervention arises only when governments value technological leadership in addition to efficiency.

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1 Introduction

Cross-border technology diffusion increasingly takes place in a politically contingent environment in which firms choose how to organize the transfer of ideas across borders. Technologies move internationally through a spectrum of arrangements, ranging from arm's-length licensing to internalization within multinational firms. These organizational forms differ in their adjustment costs and exposure to legal enforcement. Licensing contracts are renegotiated repeatedly and operate through formal legal protections, making them especially sensitive to changes in geopolitical conditions. Internalization through ownership can partially insulate firms from contractual risk, but requires large sunk investments and slower organizational restructuring. As a result, geopolitical shocks first operate through the contract-dependent frontier of technology transfer, reshaping innovation not only by altering trade volumes but by changing how the surplus from adoption is divided across countries.

This paper studies how geopolitical tensions reallocate global innovation through the interaction of contract enforcement and market access. Our empirical starting point is that royalty payments — the observable manifestation of arm's-length technology contracting — respond more strongly to geopolitical distance than merchandise trade, and this sensitivity depends sharply on the institutional environment governing intellectual property protection. Royalty flows embed both a price and a quantity margin. A deterioration in political relations can simultaneously reduce compliant technology adoption and raise the compensation innovators require to license their ideas. The net effect observed in the data reflects the joint adjustment of these margins. While reduced-form regressions cannot separately identify price and quantity responses, the interaction between geopolitical distance and institutional enforcement reveals that legally mediated technology transactions are disproportionately exposed to political risk. This pattern motivates our structural model, in which enforcement risk alters both contract pricing and diffusion volumes and, through them, the global allocation of innovation.

We develop a multi-country endogenous growth model in which cross-border technology transfer is governed by renegotiable licensing contracts subject to breach risk. Geopolitical distance raises the probability that contracts are not enforced and compresses the effective market in which technologies can be licensed. Innovators and adopters bargain over royalty rates in the presence of this risk. The exact bargaining protocol is not meant

to be taken literally; rather, it provides a tractable reduced-form representation of surplus division when outside options depend on enforcement. Any contracting environment in which political risk alters continuation values would generate a similar repricing logic. The key mechanism is that geopolitical shocks change both the scale of adoption and the surplus split, and innovation responds to the joint evolution of these two margins.

A central implication of the model is that fragmentation reshapes the geography of innovation. When geopolitical distance rises, innovators reprice contracts to insure against breach, but adoption volumes contract. Whether frontier research strengthens or weakens depends on which margin dominates. Market compression reduces the expected diffusion base and lowers the value of innovation, while contract repricing reallocates surplus toward innovators. The interaction of these forces determines how research effort shifts across countries. Growth effects can be modest even when the reallocation of innovation is large, because geopolitical shocks primarily redirect where ideas are produced and adopted rather than eliminating innovation altogether. The model therefore predicts the emergence of technology blocs and asymmetric leadership shifts as a natural equilibrium response to political rivalry.

We focus on licensing because it provides the cleanest mapping between geopolitical policy and private technology contracting. Contemporary technology controls, such as export restrictions, entity listings, and limits on knowledge sharing, intervene directly in legally enforceable rights to use intellectual property. Licensing contracts therefore offer a transparent window into how political risk enters surplus division and diffusion decisions. By isolating this contract-dependent margin, the model captures the channel through which policy most immediately reshapes innovation incentives.

Quantitatively, we calibrate the model to trade flows, royalty payments, R&D intensity, patent stocks, and international citation patterns across eight global regions. The calibration targets moments that jointly discipline innovation, adoption, and licensing activity. Counterfactual experiments show that shutting down either contract repricing or market-size adjustments does not reproduce the observed reallocation of innovation under fragmentation. The price–quantity interaction is essential. Sensitivity exercises demonstrate that this qualitative mechanism is robust to wide parameter variation, indicating that the results are not driven by knife-edge calibration.

The contractual structure of cross-border innovation generates a dynamic wedge be-

tween private incentives and national objectives. Firms price technology transfers based on expected enforcement and current surplus, but they do not internalize how diffusion decisions affect the future location of frontier research and the evolution of technological leadership. Because innovation today shapes the scale and direction of tomorrow's growth, governments evaluate technology flows through an intertemporal lens that private contracts do not capture. This dynamic externality creates a natural role for optimal policy. Our framework allows governments to value both consumption and the future position of their domestic innovation sector, and we characterize how optimal intervention reflects the trade-off between efficient diffusion and strategic control over the growth frontier.

Literature Review This paper connects to several strands of research on growth, trade, and technology diffusion. A large literature shows that market size influences innovation incentives. Models of endogenous growth emphasize that scale and competition shape the returns to R&D (Aghion and Howitt, 1992; Aghion et al., 2005). In open-economy settings, trade integration affects growth through specialization, scale, and knowledge diffusion (Grossman and Helpman, 1991, 1994; Eaton and Kortum, 2001). These frameworks establish that market access matters for innovation, but typically treat innovation rents as functions of scale rather than outcomes of contractual renegotiation.

A related literature studies the contractual structure of technology diffusion. Licensing agreements determine how surplus from innovation is divided across countries, and enforcement affects incentives to innovate and imitate (Glass and Saggi, 1999; Acemoglu and Akcigit, 2012; Santacreu, 2025). While these models highlight the role of intellectual property and imitation, they typically treat licensing terms as fixed or exogenously specified. In particular, Santacreu (2025) studies how IPR institutions shape technology transfer in a dynamic trade environment but abstracts from endogenous contract renegotiation under geopolitical risk. We extend this work by embedding Nash bargaining with breach risk into a multi-country growth framework in which contract terms adjust to political frictions. Geopolitical shocks therefore alter surplus division and feed back into the allocation of R&D.

Our empirical motivation builds on work documenting the role of geopolitical alignment in shaping international economic relationships. Surveys in Aiyar, Presbitero, and

Ruta (2023) show that fragmentation affects trade, technology, and financial flows simultaneously. We contribute by demonstrating that the sensitivity of cross-border transactions depends on institutional enforcement. Royalty flows are more responsive to geopolitical distance than merchandise trade in weak IPR environments, consistent with licensing margins being especially exposed to compliance risk.

The paper also relates to research on strategic trade and innovation policy. Dynamic models of technological rivalry show how policy can redirect innovation across countries (Bai, Jin, and Lu, 2023; Bai et al., 2025; Fornaro and Wolf, 2025). In these frameworks, governments influence innovation primarily through market access or direct policy instruments. We complement this literature by introducing an endogenous contracting channel. Geopolitical shocks alter adopters' outside options in bargaining, changing the division of surplus and reshaping innovation geography even in the absence of active intervention. Policy emerges as a response to these equilibrium reallocations rather than as an exogenous driver.

We focus on arm's-length licensing to isolate the contract-sensitive margin of technology transfer. Multinational investment, joint ventures, and other organizational forms are important vehicles for knowledge diffusion (Holmes, McGrattan, and Prescott, 2015; Choi et al., 2025), and can be interpreted as alternative governance responses to imperfect enforcement. These arrangements bundle technology with capital allocation and ownership structures, making it harder to separately observe pricing and adoption decisions. Licensing contracts provide a cleaner theoretical and empirical window: they are explicitly priced, periodically renegotiated, and directly expose the price–quantity tradeoff central to our mechanism. Recent policy interventions operate primarily on legally enforceable rights to use technology, making this margin the natural setting for analysis.

Finally, our contracting environment builds on the incomplete-contracting tradition in which surplus division depends on enforcement and outside options (Grossman and Hart, 1986; Hart and Moore, 1990; Antras, 2003). In these frameworks, changes in enforceability alter the allocation of surplus without necessarily changing technological fundamentals. We embed this logic into a multi-country growth setting in which the enforceability of cross-border technology contracts becomes politically contingent. Unlike standard incomplete-contracting models where enforcement is institutional and static, geopolitical shocks make contract credibility bilateral and state-dependent. This feature links

the contract theory of surplus division to the macroeconomics of innovation and trade, connecting to work on institutions and trade (Nunn, 2007; Levchenko, 2007; Antràs and Chor, 2013) and to models of technology licensing and imitation (Glass and Saggi, 1999; Acemoglu and Akcigit, 2012; Santacreu, 2025).

The remainder of the paper is organized as follows. Section 2 presents the empirical evidence on the relationship between geopolitical distance, trade flows, and technology transfer. Section 3 develops the quantitative model and characterizes its equilibrium properties. Section 4 analyzes the BGP and the mechanisms through which geopolitical tensions affect economic outcomes. Section 5 presents the welfare function, augmented to account for national-security concerns. Section 6 conducts counterfactual policy analysis. Section 7 concludes with policy implications and directions for future research.

2 Empirical Strategy

In this section we document empirical relationships between geopolitical distance, bilateral merchandise trade, and cross-border technology-related payments. We proxy technology-related transactions using receipts of royalty and license fees, which capture formal, contract-based exchanges of proprietary knowledge.

Our dataset covers bilateral flows among 44 countries over 2007–2021, a period spanning the intensification of geopolitical tensions associated with the escalation of U.S.–China technology rivalry and Russia's divergence from Western economies. Merchandise trade data come from BACI-CEPII, which harmonizes customs records worldwide, while royalty and license fee flows are drawn from OECD International Trade in Services statistics. Geopolitical distance is measured using ideal-point distance in UN General Assembly voting following Bailey, Strezhnev, and Voeten (2017) and the implementation in Airaud et al. (2025). To emphasize persistent alignment patterns rather than short-run fluctuations, we use the post-2007 average of this measure.

As a key conditioning variable, we include the strength of IPR protection in the importing country, measured by the International Property Rights Index. Differences in IPR regimes shape the institutional environment governing cross-border technology transactions and may be correlated with how political misalignment is reflected in observed flows. Additional controls include standard gravity covariates from CEPII—log

geographic distance, contiguity, common language, and trade agreements. Exporter–year and importer–year fixed effects absorb time-varying country characteristics and multilateral resistance terms.

We estimate the following structural gravity equation using Poisson Pseudo-Maximum Likelihood (PPML):

$$Y_{ijt} = \exp\left(\beta_1 \log GP_{ij} + \beta_2(\log GP_{ij} \times IPR_j) + \beta_3 IPR_j + \beta_4 X_{ijt} + \delta_{it} + \gamma_{jt}\right)\epsilon_{ijt}, \quad (1)$$

where Y_{ijt} denotes either bilateral merchandise exports or royalty payments from exporter i to importer j in year t, $\log GP_{ij}$ measures geopolitical distance, IPR_j is the IPR index in the importing country, and X_{ijt} is the vector of gravity controls. The interaction term allows us to test whether the adverse effect of geopolitical distance is moderated in high-IPR environments.

Table 1: Geopolitical Distance, IPR, and Bilateral Trade and Royalties (PPML, 2007–2021)

	No Interaction		With Interaction	
	Trade	Royalties	Trade	Royalties
Log Geopolitical Distance	-0.034***	0.149***	-0.169***	-0.536***
	(-3.47)	(7.00)	(-7.59)	(-11.28)
Geo × IPR	–	–	0.225***	0.916***
			(7.09)	(14.14)
FTA/WTO	0.460***	0.097*	0.452***	0.211***
	(16.43)	(2.01)	(16.02)	(4.47)
Log Distance	-0.596***	-0.350***	-0.601***	-0.331***
	(-55.33)	(-16.17)	(-55.94)	(-14.70)
Contiguity	0.558***	-0.145*	0.571***	-0.096
	(19.93)	(-2.25)	(20.32)	(-1.45)
Common Language	0.079**	0.107	0.080**	0.047
	(2.66)	(1.87)	(2.69)	(0.83)
Observations	25,284	27,090	25,284	27,090

t statistics in parentheses.

$^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$.

PPML estimation with exporter–year and importer–year fixed effects.

Table 1 reports the estimates. In the baseline specification without the IPR interac-

tion (columns 1–2), geopolitical distance is negatively associated with merchandise trade (-0.034) but positively associated with royalty flows (0.149). At first glance this contrast appears puzzling. The key is that royalty payments embed both a price and a quantity margin. Observed royalties equal the contractual price of technology multiplied by the quantity of licensed uses. Geopolitical tension can affect these two margins in opposite directions: higher political risk may reduce the quantity of compliant technology adoption while simultaneously raising the price innovators require to license their intellectual property. A positive reduced-form correlation between geopolitical distance and royalties therefore does not imply that technology diffusion increases. It may instead reflect higher licensing prices that more than offset a contraction in compliant quantities. Interpreting royalty flows requires explicitly recognizing this price–quantity decomposition.

To account for cross-country heterogeneity in institutional environments, we augment the specification by interacting geopolitical distance with destination-country IPR protection. This extension allows the balance between the price and quantity margins to vary systematically with enforcement conditions. Where legal protection is weaker, innovators face greater risk of contract breach and therefore demand stronger price compensation, while compliant quantities may fall more sharply. In high-IPR destinations, stronger enforcement attenuates breach risk, muting the repricing response and stabilizing licensed volumes.[1]

Once the interaction with IPR protection is introduced (columns 3–4), the price–quantity distinction becomes visible in the estimates. For royalties, the coefficient on geopolitical distance turns negative (-0.536), while the interaction term is positive and large (0.916). This pattern indicates that in weak-enforcement environments the contraction in licensed quantities dominates the price increase, reducing total royalty payments, whereas strong IPR protection dampens the quantity decline and limits repricing. By contrast, merchandise trade—where transactions are less dependent on licensing compliance—exhibits a smaller moderating role for IPR (0.225).

These estimates reveal that geopolitical fragmentation disproportionately disrupts

[1]The interaction specification also helps mitigate a potential composition effect. High-IPR destinations—often high-income and low-tax jurisdictions—can be disproportionately represented in reported royalty flows because multinational firms record intercompany licenses where intellectual property is legally held rather than where it is ultimately used. In that case, a positive baseline coefficient may partly reflect reporting and profit-shifting patterns rather than underlying technology utilization. The Appendix explores this channel in greater detail.

contract-based technology exchange relative to goods trade. Royalty flows, precisely because they rely on enforceable licensing agreements, are especially sensitive to the institutional environment governing compliance.

While the reduced-form regressions establish this asymmetry, they cannot isolate the underlying mechanism. Royalty payments combine price and quantity adjustments, so the data alone do not reveal whether geopolitical risk operates primarily through contract repricing, reduced adoption, or their interaction. Explaining why technology transactions respond more strongly than goods trade therefore requires a framework in which enforcement risk reshapes both margins simultaneously.

To address this problem, we develop a structural model in which firms engage in trade and technology licensing under geopolitical and institutional frictions. Geopolitical distance raises breach risk and compresses the effective market for licensing, altering both adoption volumes and the contractual division of surplus. These endogenous price and quantity responses aggregate into the royalty and trade patterns observed in the data and form the basis for our quantitative analysis of innovation reallocation.

3 Model

Guided by the empirical patterns, we develop a model in which geopolitical tensions alter the enforcement of international licensing contracts and, through them, the allocation of technology across countries. There are M countries in the world economy, indexed by i and n. Time is discrete and indexed by t.

Each country has four types of agents. Final goods producers combine traded intermediate varieties under perfect competition. Intermediate producers are monopolistic competitors and produce differentiated varieties using labor. Innovators develop new blueprints for intermediate varieties through R&D investment, and adopters decide whether to implement these foreign technologies legitimately by paying royalties or attempt to imitate them without compensation. The interaction between innovators and adopters is governed by Nash bargaining over licensing terms, which determines the royalty rate and the extent of legitimate technology transfer. Intermediate goods are traded and face iceberg transport costs.

Two key frictions shape these relationships. First, geopolitical distance raises both

trade costs and technology transfer barriers by increasing the risk of contract breach. Second, IP enforcement determines the degree of protection that innovators receive against contract breach, influencing the incentives for both licensing and imitation. These frictions create barriers for trade flows, royalty payments, and knowledge transfers through both legitimate and illegitimate channels, leading to strategic responses by firms.

3.1 Household

Each country admits a representative household that maximizes the lifetime utility

$$U_{n,t} = \sum_{s=t}^{\infty} \beta^{s-t} \ln(C_{n,s}), \tag{2}$$

where β is the discount factor and $C_{n,s}$ is the consumption of country n at time s, subject to the budget constraint

$$P_{n,t}C_{n,t} + P_{n,t}B_{n,t+1} = W_{n,t}L_{n,t} + \Pi_{n,t}^{all} + P_{n,t}R_tB_{n,t} + IBT_{n,t}, \tag{3}$$

where $P_{n,t}$ is the price index, $W_{n,t}$ is the wage, $L_{n,t}$ is the labor endowment, $\Pi_{n,t}^{all}$ is the total profits of all firms in country n, and $B_{n,t}$ is the one-period risk-free bond that is traded internationally at world interest rate R_t. The last term $IBT_{n,t}$ is the lump-sum transfer from the government generated from tariff revenue. The household consumes, invests, supplies labor inelastically, and owns all firms.

3.2 Final Production

In each country, there is a final good $Y_{n,t}$ produced under perfect competition with a constant elasticity of substitution ($\sigma > 1$) production function

$$Y_{n,t} = \left(\sum_{i=1}^{M} \int_{j=1}^{T_{it}} x_{ni,t}(j)^{\frac{\sigma-1}{\sigma}} dj \right)^{\frac{\sigma}{\sigma-1}} \tag{4}$$

where $x_{ni,t}(j)$ is the intermediate input j demanded by country n and produced from country i at time t; T_{it} is the mass of intermediate goods produced in country i. This

yields the demand for intermediate goods:

$$x_{ni,t}(j) = \left(\frac{p_{ni,t}(j)}{P_{n,t}}\right)^{-\sigma} Y_{n,t} \tag{5}$$

where $p_{ni,t}(j)$ is the respective price for an intermediate input j from country i paid by country n. And the aggregate price index $P_{n,t}$ can be derived as

$$P_{n,t} = \left(\sum_{i=1}^{M} \int_{j=1}^{T_{it}} p_{ni,t}(j)^{1-\sigma} dj\right)^{\frac{1}{1-\sigma}} \tag{6}$$

3.3 Intermediate Production

Assume there is a continuum of monopolistic competitive intermediate producers. They produce good j with a linear production function

$$y_{n,t}(j) = \Omega_{nt} l_{n,t}(j), \tag{7}$$

where Ω_{nt} is the country-specific productivity and $l_{n,t}(j)$ is the labor inputs hired by that firm. Given the input demand, the intermediate producer maximizes profits

$$\pi_{nt}(j) = \sum_{i=1}^{N} p_{in,t}(j) x_{in,t}(j) - W_{nt} l_{nt}(j) \tag{8}$$

3.4 International Trade

Intermediate goods are traded internationally. Trade is costly because of: (i) tariff $\tau_{in,t}$ levied on imports, and (ii) iceberg transport cost d_{in}, which can be generalized as $d_{in} = (d_{in}^G)^{\kappa^G}(d_{in}^P)^{\kappa^P}$. Different from the traditional settings, our specification breaks down this barrier into two sources which are *geographical distances* and *political distances*. This specification allows us to calibrate the responsiveness of trade flows to these two measures of distances. We can derive the import share as

$$s_{ni,t} = \frac{\Omega_{it}^{\sigma-1} T_{it} (W_{it} d_{ni} (1 + \tau_{ni,t}))^{1-\sigma}}{\sum_{m=1}^{N} \Omega_m^{\sigma-1} T_{mt} (W_{mt} d_{nm} (1 + \tau_{nm,t}))^{1-\sigma}} \tag{9}$$

3.5 Innovation

In each country n, a monopolist invests H_{nt}^R units of final production to introduce a new idea or technology. The number of new technologies invented is given by

$$\Delta Z_{nt} = \lambda_n Z_{nt}^w \left(\frac{H_{nt}^R}{\bar{Y}_t} \right)^{\beta^R}, \tag{10}$$

where $\Delta Z_{nt} = Z_{n,t+1} - Z_{nt}$, and Z_{nt} is the stock of invented technologies. The term $\lambda_n Z_{nt}^w$ represents innovation efficiency, where λ_n is a country-specific innovation productivity parameter, and Z_{nt}^w captures global knowledge spillovers. In particular,

$$Z_{nt}^w = \sum_{i=1}^{M} \gamma_{ni} Z_{it},$$

where Z_{it} is the stock of technologies invented in country i, and $\gamma_{ni} \in [0, 1]$ is a weight that reflects the ease with which ideas from i diffuse to n. These weights are taken as exogenous. The key point is that Z_{nt}^w measures the set of ideas that reach country n through diffusion, regardless of whether they are adopted for production. In other words, it is the global "knowledge pool" accessible to n at time t, which shapes the productivity of domestic innovation efforts even before considering adoption decisions.

The term $\bar{Y}_t = \sum_{m=1}^{M} Y_{mt}$ is world output, and $\beta^R \in (0, 1)$ reflects diminishing returns to innovation. An innovator chooses $H_{n,t}^R$ to maximize

$$V_{nt}(Z_{n,t+1} - Z_{nt}) - P_{nt} H_{nt}^R, \tag{11}$$

where V_{nt} is the value of an innovation, to be defined later.

Ideas are blueprints that can be used in the production of differentiated intermediate goods. These ideas must be adopted prior to their use, as described below.

3.6 Adoption and Technology Licensing

In each country, adopters invest resources to adopt technologies created elsewhere. We assume a unit–measure continuum of ex-ante identical adopters $j \in [0, 1]$ who face i.i.d. compliance shocks with hazard $\phi(d_{in,t}^P)$, to be defined later. By the law of large numbers, we normalize cohort size to one and omit the j index, interpreting all variables as cohort

averages.

Adoption is costly and uncertain. Adopters in country i can invest $H^A_{in,t}$ units of final output to adopt a technology invented in country n. The probability of successful adoption is given by

$$\epsilon_{in,t} = \bar{\epsilon}_{in} \left(\frac{H^A_{in,t}}{\bar{Y}_t} \right)^{\beta^A}, \tag{12}$$

where $\bar{\epsilon}_{in}$ is the adoption productivity parameter, $\beta^A \in (0,1)$ captures diminishing returns to adoption, and $H^A_{in,t}$ is the amount of final output that adopters in country i invest to adopt technologies from country n.

The number of technologies adopted by country i, invented in country n, evolves according to

$$\Delta A_{in,t} = \epsilon_{in,t} \left(Z_{nt} - A_{in,t} \right), \tag{13}$$

where a fraction $\epsilon_{in,t}$ of the unadopted technologies $(Z_{nt} - A_{in,t})$ is adopted in period $t+1$.

The total stock of knowledge in country n is the sum of all technologies adopted from different countries:

$$T_{nt} = \sum_{i=1}^{M} A_{ni,t}. \tag{14}$$

Technology Licensing Upon successful adoption, adopters use each technology j to produce a differentiated intermediate good. Adopters pay royalties to innovators for the rights to exploit the technology in production. The licensing arrangement is modeled as a fixed-rate, $\eta_{in,t}$, profit-sharing contract. The licensing rate $\eta_{in,t}$ is determined by Nash bargaining at time t, maximizing the joint surplus of innovators and adopters:[2]

$$\underset{\eta_{in,t}}{\operatorname{argmax}} \left(V^{\text{Innov}}_{in,t} \right)^{\rho_{in}} \left(V^{\text{Adopt}}_{in,t} \right)^{1-\rho_{in}}, \tag{15}$$

where ρ_{in} is the innovator's bargaining power and $V^{\text{Innov}}_{in,t}$ ($V^{\text{Adopt}}_{in,t}$) denotes the continuation value to the innovator (adopter) from licensing the technology, to be defined formally

[2]In the symmetric equilibrium, all technologies face the same royalty fee $\eta_{in,t}$ $\forall j$.

below.

Geopolitical tensions impact the negotiation process through a probability of breach, $\phi(d_{in}^P, \text{IPR}_n) \in [0,1]$, which depends on geopolitical distance and the adopter country's IPR protection. We assume $\partial\phi/\partial d_{in}^P > 0$ and $\partial\phi/\partial \text{IPR}_n < 0$, i.e., greater geopolitical distance raises enforcement risk, whereas stronger IPR lowers it by increasing expected legal remedies, court enforceability, and reputational/market-access penalties. This breach risk enters the continuation values $V_{in,t}^{\text{Innov}}$ and $V_{in,t}^{\text{Adopt}}$ below and, through Nash bargaining, affects the equilibrium royalty rate $\eta_{in,t}$ and the surplus split.

One might argue that if technology licenses are paid entirely upfront, the risk of contract breach becomes irrelevant. In practice, however, even lump-sum agreements typically prohibit resale or unauthorized diffusion to other firms. In our model, the innovator licenses the technology to a continuum of potential adopters in the destination country. An upfront payment by one adopter represents only a fraction of the total potential market. A breach corresponds to leakage of the technology to unauthorized adopters, which reduces the continuation value of licensing in the remaining market. In this sense, our profit-sharing specification is consistent with both per-period royalty contracts and upfront payments, since in both cases the innovator's expected revenue stream depends on preventing leakage to unauthorized adopters.

The innovator's value function satisfies

$$\begin{aligned} V_{in,t}^{Innov} &= \eta_{in}\pi_{in,t} + \frac{P_{n,t}}{R_t P_{n,t+1}} \left(1 - \phi(d_{in}^P)\right) V_{in,t+1}^{Innov} \\ &= \eta_{in}\, \Upsilon_{in,t}, \end{aligned}$$

where $\pi_{in,t}$ are profits that adopters in country i make with technologies developed in country i and $\Upsilon_{in,t}$ is the discounted value of future profits from licensing when the contract remains compliant.

The adopter's value when the contract is in force is

$$\begin{aligned} V_{in,t}^{Adopt} &= (1-\eta_{in})\pi_{in,t} + \frac{P_{i,t}}{R_t P_{i,t+1}} \left[\left(1 - \phi(d_{in}^P)\right) V_{in,t+1}^{Adopt} + \phi(d_{in}^P) V_{in,t+1}^{Breach}\right] \\ &= (1-\eta_{in})\, \Upsilon_{in,t} + \Upsilon_{in,t}^{Breach}, \end{aligned}$$

where $\Upsilon_{in,t}^{Breach}$ is the continuation value associated with the breach.

Finally, once a breach occurs, the adopter receives the full profit flow in perpetuity:

$$V_{in,t}^{Breach} = \pi_{in,t} + \frac{P_{i,t}}{R_t P_{i,t+1}} V_{in,t+1}^{Breach}.$$

Both $\Upsilon_{in,t}$ and $\Upsilon_{in,t}^{Breach}$ are determined endogenously by the enforcement hazard $\phi(d_{in}^P)$ and the underlying profit stream $\pi_{in,t}$.

The royalty fee The optimal royalty fee derived from equation (15) becomes:

$$\eta_{in,t} = \rho_{in} \left[1 + \frac{\Upsilon_{in,t}^{\text{Breach}}}{\Upsilon_{in,t}} \right], \tag{16}$$

where the first term inside brackets represents breach compensation and the second represents the adjustment due to contracting costs.

Innovators pass on a relatively larger share of transaction costs to adopters through higher royalty fees. However, innovators cannot fully raise royalty fees to completely internalize higher breach probabilities. This limitation results in royalty fees that are lower than would ideally compensate innovators for the elevated risk.

3.7 Optimal Innovation and Adoption

Before the invention is adopted, its value to the innovator is given by

$$J_{in,t}^{Innov} = \frac{1}{R_t} \frac{P_{i,t}}{P_{i,t+1}} \left[\epsilon_{in,t} V_{in,t+1}^{Innov} + (1 - \epsilon_{in,t}) J_{in,t+1}^{Innov} \right]. \tag{17}$$

With probability $\epsilon_{in,t}$, this invention is adopted next period and gives the value of $V_{in,t+1}^{Innov}$. With probability $1 - \epsilon_{in,t}$, it remains unadopted and gives the continuation value $J_{in,t+1}^{Innov}$.

The value of an unadopted invention to an adopter is

$$J_{in,t}^{Adopt} = -P_{it} h_{in,t}^A + \frac{1}{R_t} \frac{P_{i,t}}{P_{i,t+1}} \left[\epsilon_{in,t} V_{in,t+1}^{Adopt} + (1 - \epsilon_{in,t}) J_{in,t+1}^{Adopt} \right]. \tag{18}$$

where $h_{in,t}^A$ is the investment to adopt technology j.

It shares a similar structure as the value of the unadopted invention to the innovator. The difference is that an adopter pays an R&D cost on adoption $P_{it} h_{in,t}^A$. Summing equation 17 across adopting countries, we obtain the total value of an innovation invented

in country n:

$$V_{n,t} = \sum_{i=1}^{N} J_{in,t}^{Innov} \tag{19}$$

In a symmetric equilibrium, every technology j generates the same value and aggregation leads to the following FOC for innovation and adoption.

The first-order condition for optimal innovation is

$$P_{n,t} H_{n,t}^{R} = \beta^{R} \left(Z_{n,t+1} - Z_{n,t} \right) V_{n,t}. \tag{20}$$

Using equation 17, the first-order condition for optimal adoption is

$$P_{i,t} h_{in,t}^{A} = \beta^{A} \epsilon_{in,t} \frac{P_{i,t}}{R_t P_{i,t+1}} \left(V_{in,t+1}^{Adopt} - J_{in,t+1}^{Adopt} \right) \tag{21}$$

and the total adoption expenditure is given by

$$H_{in,t}^{A} = h_{in,t}^{A} \left(Z_{n,t} - A_{in,t-1} \right) \tag{22}$$

3.8 Market Clearing Conditions

The final good is used for consumption, innovation, and adoption. Output market clearing implies

$$Y_{nt} = C_{nt} + H_{nt}^{R} + \sum_{i=1}^{M} H_{ni,t}^{A} \tag{23}$$

Labor is supplied inelastically and is used for the production of intermediate goods. Labor market clearing implies

$$L_{nt} = \sum_{i=1}^{M} T_{nt} \frac{x_{int} d_{in} (1 + \tau_{int})}{\Omega_{nt}} = \sum_{i=1}^{M} T_{nt} \frac{\sigma - 1}{\sigma} p_{int} x_{int} \tag{24}$$

$$\implies \frac{\sigma}{\sigma - 1} W_{nt} L_{nt} = \sum_{i=1}^{M} \frac{s_{int}}{1 + \tau_{int}} P_{it} Y_{it}. \tag{25}$$

When tariffs are positive, the revenue generated is redistributed to the household as a lump sum given by

$$IBT_{nt} = \sum_{i \neq n} \frac{\tau_{nit}}{1+\tau_{nit}} s_{nit} P_{nt} Y_{nt}. \tag{26}$$

Balance of Payments requires that the net export value equals net royalty payments, given by

$$\sum_{i \neq n} \frac{s_{nit} P_{nt} Y_{nt}}{1+\tau_{nit}} + \sum_{i \neq n} RP_{nit} = \sum_{i \neq n} \frac{s_{int} P_{it} Y_{it}}{1+\tau_{int}} + \sum_{i \neq n} RP_{int} \tag{27}$$

where the royalty payment for technology invented in country n and adopted by country i is defined as

$$\begin{aligned} RP_{in,t} = & \underbrace{\eta_{in,t}\Big(\tfrac{A_{in,t}-A_{in,t-1}}{T_{it}}\Big)\Pi_{it}}_{\text{new cohort}} + \underbrace{\sum_{s=1}^{t-1} \eta_{in,t-s} \prod_{k=1}^{s} \big(1-\phi(d^P_{in,t-k+1})\big)\Big(\tfrac{A_{in,t-s}-A_{in,t-s-1}}{T_{it}}\Big)\Pi_{it}}_{\text{older cohorts (compliant)}} \\ & + \underbrace{\eta_{in,0} \prod_{k=1}^{t} \big(1-\phi(d^P_{in,t-k+1})\big)\Big(\tfrac{A^L_{in,0}}{T_{it}}\Big)\Pi_{it}}_{\text{initial stock (compliant)}}. \end{aligned} \tag{28}$$

This equation shows that royalty payments consist of two main components: (i) royalties from newly adopted technologies in period t, using the current royalty rate $\eta_{in,t}$, (ii) royalties from previously adopted technologies whose contract has not yet been breached, which utilize historical royalty rates $\eta_{in,t-s}$ combined with cumulative contract survival probabilities that now explicitly depend on evolving geopolitical distance through $(1-\phi(d^P_{in,t-k+1}))$ terms, and (iii) royalties from the pre-existing legitimate stock $A^L_{in,0}$ that survives through t with probability $\prod_{k=1}^{t}\big(1-\phi(d^P_{in,t-k+1})\big)$ and pays at the initial rate $\eta_{in,0}$. We can define, alternatively, the legal claims to current profits $\mathcal{L}_{in,t} \equiv \eta^{\text{weighed avg}}_{in,t} \cdot \frac{A^L_{in,t}}{A_{in,t}}$ which follows the law of motions:

$$\mathcal{L}_{in,t+1} = \eta_{in,t} \cdot \frac{A_{in,t+1} - A_{in,t}}{A_{in,t+1}} + \mathcal{L}_{in,t} \cdot (1-\phi_{in,t+1}) \cdot \frac{A_{in,t}}{A_{in,t+1}} \tag{29}$$

This equation is particularly useful for understanding the effects of geopolitical shocks. An increase in d^P raises royalty rates as we discussed instantly, the response of royalty

payments is much slower because of the contracts negotiated before prevail until breaches. Therefore, both the legal claims and the royalty payments converge slowly to the new BGP.

3.9 Equilibrium

Given the initial vector $\{A_{in,0}, \mathcal{L}_{in,0}, Z_{n,0}\}$, an equilibrium is defined as a sequence of aggregate prices and wages $\{P_{nt}, W_{nt}, R_t\}_{t=0}^{\infty}$, a sequence of intermediate prices $\{p_{in,t}\}_{t=0}^{\infty}$, a sequence of royalty fees $\{\eta_{in,t}\}_{t=0}^{\infty}$, a sequence of value functions $\{V_{in,t}^A, V_{in,t}^I, J_{in,t}^A, J_{in,t}^I, V_{in,t}^B, V_{n,t}\}_{t=0}^{\infty}$, a sequence of profits and payments $\{\Pi_{nt}, RP_{in,t}\}_{t=0}^{\infty}$, a sequence of quantities $\{Y_{nt}, H_{nt}^R, H_{in,t}^A, s_{in,t}\}_{t=0}^{\infty}$, and a sequence of technology stocks $\{A_{in,t+1}, Z_{n,t+1}\}_{t=0}^{\infty}$ such that:

(i) $\{A_{in,t+1}, \mathcal{L}_{in,t+1}, Z_{n,t+1}\}_{t=0}^{\infty}$ satisfy the law of motion (13), (29), and (10);

(ii) Given prices, allocations maximize consumer utility (2) subject to budget constraint (3);

(iii) Given prices, allocations solve the final good producer's problem, yielding equation (5);

(iv) Given prices, allocations solve the intermediate good producers' problems (8) subject to demand (5);

(v) Given prices, allocations solve the innovators' and adopters' decisions, consistent with equation (20) and (21);

(vi) The royalty fees are determined as the result of Nash bargaining defined in (15);

(vii) Feasibility condition is satisfied in (23);

(viii) Prices clears all markets in equation (24), (26), and (27).

4 Balanced Growth Path

We define the BGP as an equilibrium in which aggregates grow at a common constant rate while *relative* objects are stationary. To characterize it, we stationarize the model so that relative variables are time invariant. In this representation the BGP is summarized

by a stationary vector of relative technology stocks $\{\hat{T}_n^*\}$ and a common growth rate g^*. The pair $(g^*, \{\hat{T}_n^*\})$ solves the fixed–point relation

$$g^*\,\hat{T}_i^* = \sum_{n=1}^{M} \underbrace{\frac{\epsilon_{in}^*}{\epsilon_{in}^* + g^*}}_{\text{adoption factor}} \quad \lambda_n \left(\frac{\hat{Z}_n^{w*}}{\hat{T}_n^*}\right) \left(\frac{H_n^{R*}}{\hat{Y}^*}\right)^{\beta^R} \hat{T}_n^* \;\equiv\; \sum_n \Delta_{in}(g^*;\epsilon^*)\,\hat{T}_n^*.$$

Equivalently,

$$g^*\,\hat{T}^* = \Delta(g^*)\,\hat{T}^*,$$

where $\Delta(g^*)$ includes adoption intensities and innovation productivity evaluated on the stationary allocation. Under indecomposability, Perron–Frobenius implies a unique positive eigenvalue g^* and an associated eigenvector $\{\hat{T}^*\}$.

Comparative statics: higher geopolitical distance. A permanent rise in geopolitical distance d_{ni}^P affects the BGP through two blocks of the model. First, it raises bilateral trade costs, compressing market access and the licensable demand relevant for innovators; this is the *market–size channel*. Second, it increases the breach hazard $\phi(\cdot)$ in the licensing block, altering the compliant-path value Υ_{in} and the breach continuation value $\Upsilon_{in}^{\text{Breach}}$, and therefore the negotiated royalty fee

$$\eta_{in} = \rho_{in}\big[1 + \Upsilon_{in}^{\text{Breach}}/\Upsilon_{in}\big];$$

this is the *breach channel*. Because geopolitical distance scales the profit stream symmetrically across compliant and breach states, contract repricing is governed by the ratio of continuation values, while market access governs the quantity of adoption. When both channels operate, compliant adoption falls between geopolitically distant countries. Royalty *rates* rise through repricing, but royalty *payments* decline because the contraction in compliant quantities dominates. Innovation effort in the leader weakens and the BGP growth rate g^* falls. The leader's relative technological position deteriorates because the contraction in its innovation sector dominates the follower's residual catch-up.

Two decompositions, reported in the Appendix, clarify these forces. In the first, we shut down the market–size effect and let d^P operate only through breach. Contract repricing still occurs, but the scale of the licensable market is preserved. Adoption responds only through enforcement risk rather than through market compression. Higher

η reallocates surplus toward innovators, raising the expected value of innovation and strengthening frontier R&D. In this environment relative technological leadership can improve despite higher contractual risk.

In the second decomposition, we insulate breach and let d^P operate only through market size. Contract terms remain largely unchanged, but the smaller licensable market compresses compliant adoption and innovator returns. The reduction in diffusion volumes lowers research intensity and the common growth rate. Leadership declines through the innovation margin.

These experiments show that the decline in growth arises from the interaction of price and quantity adjustments. The market–size channel disciplines growth by reducing adoption volumes and the compliant continuation value $\Upsilon_{in,t}$, which lowers licensable diffusion and R&D effort $H_n^R/\bar{Y}$. The breach channel alone does not decrease adoption; it raises the ratio $\Upsilon_{in,t}^{\text{Breach}}/\Upsilon_{in,t}$ and pushes up $\eta_{in,t}$, partially reallocating surplus toward innovators.

The breach channel operates through endogenous contract repricing. A rise in geopolitical distance increases non-compliance risk and lowers the expected surplus from licensed adoption. Under Nash bargaining, innovators raise the royalty fee to insure against breach. When market access is preserved, adopters remain willing to absorb higher fees and the larger diffusion base amplifies the effect of repricing on innovation value. Because follower economies rely more heavily on imitation rents, their incentives contract more sharply than those of the frontier economy, tilts relative innovation effort toward the leader.

When the market–size channel is active, the quantity margin dominates. Higher geopolitical distance shrinks the licensable market faced by frontier innovators. Adoption responds weakly despite repricing, so the increase in royalty rates does not translate into higher innovation value. Frontier R&D declines, and follower economies reallocate effort toward domestic innovation as an equilibrium response to reduced access to frontier technologies.

5 Quantitative Analysis

In this section, we conduct a quantitative analysis to examine how geopolitical tensions affect technology transfers and trade. We calibrate the model to data on trade flows, royalty payments, R&D intensity, patent and citations data, and other standard gravity and macroeconomic variables. We group our sample of countries into 8 regions—the United States, the Euro Area, Mexico, Canada, South Korea, Japan, China, and an aggregate rest of the world—for the period 2000-2020.

We begin by calibrating the model along a transition path covering the period 2000–2020, a phase characterized by relatively low geopolitical tensions. This baseline allows us to match key moments in the data under conditions of stable geopolitical relations. We then introduce an increase in geopolitical rivalry in 2020 and trace its effects on trade, technology adoption, innovation, and welfare. Welfare is measured in consumption-equivalent units, but to better understand the temporal dynamics we also plot the path of aggregate consumption relative to the initial BGP, hence capturing both the short-run adjustment costs and the long-run consequences of heightened geopolitical tensions.

In the second step, we study the optimal policy responses. We first consider a government that maximizes lifetime household consumption and assess the consequences of implementing unilateral technology export controls. These controls are modeled as bilateral instruments that can be targeted toward specific destination countries. We then extend the analysis by explicitly incorporating national security considerations into the government's objective function. Specifically, we augment government preferences to depend not only on household consumption, but also on the bilateral technological gap with trading partners. This national security component is weighted by a term that interacts geopolitical distance with the strength of IPR enforcement in the destination country. The resulting formulation captures the idea that national security concerns are more acute vis-a-vis geopolitically distant partners and when IPR protection is weak, hence providing a rationale for welfare-reducing technology export restrictions in some bilateral relationships. The algorithm to solve for the BGP and the transitional dynamics is reported in Appendix B.

5.1 Calibration Strategy

The calibration of the model proceeds in several steps, combining direct data sources, estimates from the literature, and structural regressions. We focus on the period 2000–2020 and the set of WIOT countries augmented with Vietnam. The guiding principle is to use direct data whenever possible, estimate elasticities through gravity regressions, and rely on method-of-moments for the remaining structural parameters.

We begin with parameters that can be directly measured from data. Country labor endowments L_n and expenditure shares are taken from national accounts. Geopolitical distance d_{in}^P is measured using ideal-point distances based on United Nations voting records, while geographical distance d_{in}^G is obtained from CEPII. These quantities are treated as exogenous primitives of the model.

A second set of parameters is borrowed from the literature. We fix the elasticity of substitution across varieties σ, the discount factor β, and the bargaining parameter ρ at values consistent with standard quantitative trade and growth models.

Trade Flows We then estimate the responsiveness of trade flows to distance through a series of structural gravity regressions. Trade flows are taken from the CEPII BACI dataset, and we regress bilateral imports on geographical distance and political distance. The estimated elasticities deliver values for κ^G and κ^P. The procedure closely follows the state-of-the-art gravity methodology described in Yotov et al. (2016).

Specifically, we estimate gravity with *trade shares* on the left-hand side. Using CEPII BACI, we run

$$\ln s_{in,t} = \alpha_{i,t} + \delta_{n,t} - \kappa^G \ln d_{in}^G - \kappa^P \ln d_{in}^P + \epsilon_{in,t}, \tag{30}$$

where $s_{in,t} \equiv X_{in,t} / \sum_m X_{mn,t}$ is the import share of n from i in year t, and $\alpha_{i,t}$ and $\delta_{n,t}$ are exporter–year and importer–year fixed effects that absorb multilateral resistance. The distance elasticities κ^G and κ^P map into the bilateral iceberg term

$$d_{in} \;=\; \left(d_{in}^G\right)^{\kappa^G} \left(d_{in}^P\right)^{\kappa^P}, \tag{31}$$

From the model, bilateral trade shares satisfy

$$s_{in,t} = \frac{\Omega_{i,t}^{\sigma-1} T_{i,t} \left(W_{i,t} \tilde{d}_{in,t}\right)^{1-\sigma}}{\sum_m \Omega_{m,t}^{\sigma-1} T_{m,t} \left(W_{m,t} \tilde{d}_{mn,t}\right)^{1-\sigma}}. \tag{32}$$

Table 2: Table 2: Estimated Total Trade Costs d_{in}^{total}

Importer \ Exporter	USA	CAN	MEX	EU	CHN	JPN	KOR	ROW
USA	–	6.257	7.779	10.811	7.598	8.813	10.582	15.594
CAN	1.799	–	4.514	5.542	3.845	4.352	5.246	8.306
MEX	3.169	6.426	–	6.874	4.177	5.140	6.182	8.174
EU	3.651	6.190	5.828	–	3.809	4.408	4.763	6.767
CHN	6.219	10.948	8.483	8.878	–	4.847	5.053	10.209
JPN	5.319	9.075	7.438	7.857	3.626	–	4.469	8.902
KOR	4.276	7.348	6.004	6.146	2.515	3.007	–	7.308
ROW	3.082	5.554	3.796	4.053	2.569	3.530	4.052	–

Notes: Table reports bilateral total trade costs d_{in}^{total}, combining standard iceberg costs and geopolitical costs. Exporters are columns, importers are rows. Diagonal entries are domestic trade.

Comparing (30) and (32), the exporter fixed effect identifies the composite "capability"

$$\alpha_{i,t} \equiv \log S_{i,t} = (\sigma - 1) \log \Omega_{i,t} + \log T_{i,t} + (1 - \sigma) \log W_{i,t} + \text{const.} \tag{33}$$

Given wages $W_{i,t}$ (from the wage/BoP block or national accounts) and the mass of varieties $T_{i,t}$ (from the adoption block), we back out exporter productivity as

$$\Omega_{i,t} = \left(\frac{\exp\{\alpha_{i,t}\}\, W_{i,t}^{\sigma-1}}{T_{i,t}} \right)^{1/(\sigma-1)}. \tag{34}$$

We pin down the irrelevant constant by a normalization (e.g., $\frac{1}{N}\sum_i \log \Omega_{i,t_0} = 0$ at a base year or $\Omega_{\text{USA},t_0} = 1$). In practice, we estimate (30) by PPML with exporter–year and importer–year fixed effects, construct bilateral costs via (31), and then recover $\Omega_{i,t}$ using (34).

Adoption Probability We calibrate bilateral technology adoption probabilities using international patent citation flows, following the methodology of Caballero and Jaffe (1993) and Cai, Li, and Santacreu (2022). Patent citations are informative about cross-border knowledge flows: when a patent in country d cites prior art from country o, this is evidence that knowledge originating in o has been adopted in d. We interpret the intensity of these citations as a measure of diffusion and map it into an adoption probability.

The data are from from INPACT-S, which records the citing and cited inventor's countries as well as application years. To account for bilateral frictions, we merge in geography variables from CEPII (distance, contiguity, common language) and a measure of

Table 3: TFP and GDP per Capita Relative to the United States (Backed Out from Gravity)

Region	TFP (USA = 1)	GDP per Capita (USA = 1)
USA	1.000	1.000
CAN	0.823	0.724
MEX	0.587	0.152
EU	0.733	0.573
CHN	0.523	0.163
JPN	0.903	0.615
KOR	0.742	0.506
ROW	0.470	0.074

Notes: TFP and relative GDP per capita are normalized to the United States (=1). TFP is backed out from the gravity regressions, while relative GDP per capita is taken from national accounts, averaged over 2017–2020.

geopolitical distance from Bailey, Strezhnev, and Voeten (2017). Intra-country citations are excluded. To absorb time-varying differences in innovation scale, we include fixed effects by origin-year and destination-year.

We then estimate a PPML gravity model of citation flows. Let C_{odt} denote the number of citations from origin o to destination d in year t. The regression takes the form

$$C_{odt} \;=\; \exp\Big(\beta_1 \ln \text{dist}_{od} + \beta_2 \text{contig}_{od} + \beta_3 \text{comlang}_{od} + \beta_4 \ln \text{geo}_{od} + \alpha_{o,t} + \delta_{d,t}\Big) + \epsilon_{odt}, \quad (35)$$

where $\alpha_{o,t}$ and $\delta_{d,t}$ are the origin-time and destination-time fixed effects. The fitted bilateral index

$$\text{pair}_{od} = \hat{\beta}_1 \ln \text{dist}_{od} + \hat{\beta}_2 \text{contig}_{od} + \hat{\beta}_3 \text{comlang}_{od} + \hat{\beta}_4 \ln \text{geo}_{od}$$

summarizes how geography and geopolitics affect citation intensity.

To map this continuous index into a probability of adoption, we use a logistic transformation,

$$\widehat{p}_{od}^{\text{adopt}} \;=\; \frac{1}{1 + \exp[-\,\text{pair}_{od}]}, \quad (36)$$

ensuring values in $(0, 1)$. Next, we interpret adoption as a Bernoulli event occurring within a horizon of L_{od} years, defined as the lag between the cited and citing patents. If

ϵ_{od} denotes the per-year adoption hazard, the probability of adoption within L_{od} years is

$$p_{od}^{\text{adopt}} = 1 - \exp(-\epsilon_{od} L_{od}). \tag{37}$$

Equating this to the logistic estimate yields a closed-form calibration of the hazard:

$$\widehat{\epsilon}_{od} = -\frac{1}{L_{od}} \ln\left(1 - \widehat{p}_{od}^{\text{adopt}}\right). \tag{38}$$

Finally, we aggregate these bilateral hazards to the regional level by averaging over all country pairs within each pair of regions. The resulting matrix of hazards $\{\widehat{\epsilon}_{od}\}$ forms the adoption block of our quantitative model. This approach ensures that geography and geopolitics directly shape the probability that knowledge produced in one region is adopted in another, consistent with the citation-based measures of diffusion proposed by Caballero and Jaffe (1993) and applied in Cai, Li, and Santacreu (2022).

Table 4: Estimated Adoption Intensities ϵ_{in}

Adopter \ Innovator	USA	CAN	MEX	EU	CHN	JPN	KOR	ROW
USA	0.333	0.247	0.106	0.140	0.103	0.111	0.114	0.135
CAN	0.247	0.333	0.153	0.188	0.114	0.137	0.138	0.152
MEX	0.107	0.149	0.333	0.134	0.154	0.135	0.133	0.188
EU	0.141	0.188	0.134	0.333	0.127	0.176	0.178	0.157
CHN	0.104	0.114	0.154	0.127	0.333	0.179	0.204	0.166
JPN	0.115	0.139	0.135	0.176	0.179	0.333	0.325	0.138
KOR	0.116	0.139	0.133	0.179	0.204	0.326	0.333	0.141
ROW	0.132	0.150	0.192	0.161	0.159	0.143	0.142	0.333

Notes: Table reports estimated bilateral adoption efficiencies ϵ_{in}, where rows correspond to adopters (i) and columns to innovators (n). Diagonal terms are normalized to 0.33, reflecting the assumption that countries adopt their own innovations within three years on average. Off-diagonal terms are estimated using citation-based gravity regressions for the period 2017–2021. This serves as a targeted moment in the model calibration. The model-implied values are reported in the Appendix.

Innovation Innovation parameters are disciplined using patenting and R&D data. We construct patent stocks from annual patent flows using the perpetual inventory method with a depreciation rate of 15%. R&D intensity is taken from the World Bank's World Development Indicators, expressed as a fraction of world GDP to remain consistent with the model's scaling. Citation data come from INPACTS (LaBelle et al., 2023) and are used to calibrate the adoption probabilities ϵ_{in} through gravity regressions, mapping the

bilateral probability of knowledge diffusion to political and geographic distances. This step identifies the parameters λ_n, β^R, and β^A, which govern the shape of the innovation and adoption functions. We then regress innovation flows on R&D intensity:

$$\Delta Z_{n,t}/Z_{nt}^w = \lambda_n \left(\frac{RD_{n,t}}{\bar{Y}_t} \right)^{\beta^R}, \tag{39}$$

where λ_n is country-specific innovation efficiency (calibrated to target R&D intensities) and β^R is the curvature parameter of the innovation function (obtained from regression estimation). Moreover, the average distribution of patent stock from 1996-2000 is used to proxy the initial distribution of blueprints $Z_{n,0}$. Since the system is homogeneous of degree one, the level of $Z_{n,0}$ is irrelevant; we can normalize $Z_{n,0}/\sum_n Z_{n,0}$ as the initial condition.

Table 5: R&D Intensity, Macroeconomic Statistics, Patent Stocks, and Innovation Efficiency (Averages 2017–2021)

Region	R&D Intensity (%)	World GDP (bill. USD)	GDP (bill. USD)	Population (bill.)	Patent Stock	λ_n
USA	3.2	75800	21369	0.330	992708	0.1634
CAN	1.8	75800	1759	0.038	75042	0.0191
MEX	0.3	75800	1238	0.126	2942	0.0092
EU	1.7	75800	19228	0.518	961228	0.0518
CHN	2.3	75800	14889	1.406	105060	0.1078
JPN	3.2	75800	5037	0.126	1016114	0.0748
KOR	4.6	75800	1693	0.052	243966	0.0318
ROW	1.2	75800	10602	2.226	442591	0.0425

Notes: GDP and World GDP are expressed in billions of USD. The population is expressed in billions of people. Patent stocks are reported in raw counts and constructed using a perpetual inventory method with a 15% depreciation rate. All values are averages over 2017–2021. The estimated curvature of the innovation function is $\beta^R = 0.3843$.

The remaining set of parameters $\{\Omega_n, \bar{\epsilon}_{in}, \lambda_n, \gamma, \kappa^\phi\}$ and the initial states $\{A_{in,0}, \mathcal{L}_{in,0}\}$ are jointly calibrated by a method-of-moments procedure. We target the empirical moments that capture both aggregate dynamics and bilateral technology flows:

Formally, the calibration minimizes the distance between simulated and empirical moments:

$$\min_{\{\gamma,\kappa^\phi,\bar{\epsilon}_{in},\Omega_n,\lambda_n,A_{in,0},\mathcal{L}_{in,0}\}} \|M^{\text{model}} - M^{\text{data}}\|,$$

where M^{model} are model-implied moments and M^{data} their empirical counterparts. The computational procedure follows a sequence of iterations.

[2]Average royalty payment shares is defined as $RP - share_{n,t} = \frac{\sum_n RP_{in,t}}{\sum_i \sum_n RP_{in,t}}$.

Param/Initial States	Targeted Moments
Ω_n	Total factor productivity
$\bar{\epsilon}_{in}$	Average adoption efficiency (2000-2020)
λ_n	R&D expenditure to GDP ratio
γ	Long run growth rate
κ^{ϕ}	Regression coefficient of royalty payments on d^P
$A_{in,0}$	Initial transitional output growth rates (2001-2005)
$\mathcal{L}_{in,0}$	Average royalty payment shares (2001-2020)

Table 6: Parameters/initial states and targeted moments

(i) Guess the BGP values of $\{TFP_n^*, \epsilon_{in}^*, \frac{H_n^R}{Y}, g^*\}$. The computed allocation gives $\{\Omega_n, \bar{\epsilon}_{in}, \lambda_n, \gamma\}$

(ii) Set the initial state $Z_{n,0}$ at average patent stock distribution over 1996-2000. Guess $A_{in,0}$ and $\mathcal{L}_{in,0}$ and utilize the imputed parameters to compute the evolution of $A_{in,t}$ and $\mathcal{L}_{in,t}$.

(iii) Compute the transition path using the solution algorithm in the Appendix. Compare the simulated transitional output growth rates and the average royalty payment shares and update $A_{in,0}$ and $\mathcal{L}_{in,0}$ accordingly

(iv) Compute the average adoption intensities $\epsilon_{in,t}$ along the transition path, update the BGP guess ϵ_{in}^* accordingly which leads to new imputed $\bar{\epsilon}_{in}$, and then repeat step (i)-(iii) until converge

(v) Run the gravity regression of $RP_{in,t}$. Compare against empirical estimates to calibrate the remaining parameter κ^{ϕ}

The calibrated parameters are summarized in the following tables:

Parameters	Description	Value
β	Discount rate	0.96
β^A	Adoption curvature	0.3843
β^R	Innovation curvature	0.3843
σ	Elasticity of Substitution	5
ρ	Innovator's bargaining power	0.25
κ^G	Trade–geography elasticity	1
κ^P	Trade–politics elasticity	0.1030
κ^{ϕ}	Breach–politics elasticity	0.0923
γ	Innovation scale	1.6227

Param	Description	USA	CAN	MEX	EU	CHN	JPN	KOR	ROW
λ_i	Innovation efficiency	0.1634	0.0191	0.0092	0.0518	0.1078	0.0748	0.0318	0.0425
L_i	Labor endowment	1.0000	0.1105	0.3674	1.6440	4.3432	0.4128	0.1607	6.5303
Ω_i	Productivity	0.6219	0.5121	0.3708	0.4570	0.3405	0.5609	0.4628	0.2942
ξ_i	IPR enforcement	0.9432	0.9709	0.4535	0.7358	0.1597	0.8686	0.8268	0.5368

The simulated model produces regression coefficients for $\log(RP_t)$ as a function of geopolitical distance, IPR enforcement, and geography. We align the model-implied coefficients with their empirical counterparts and adjust κ^ϕ (the elasticity of breach to political distance) to minimize the gap, focusing especially on the coefficient of $\log(d^P - 1)$.

	Model	Data
$\log(d^P - 1)$ [Targeted]	-0.40503	-0.40502
$\log(d^P - 1)\times$IPR	0.36131	0.91618
$\log(d^G)$	-0.35231	-2.39780

Table 7: Regression of $\log(RP_t)$ on geopolitical and geographic distance and IPR enforcement: model-implied vs. data coefficients.[3]

Region	GDP growth rates(%)		Royalty payment shares	
	Model	Data	Model	Data
USA	2.537	2.557	0.143	0.168
CAN	2.594	2.597	0.018	0.044
MEX	1.229	1.235	0.024	0.018
EU	1.815	1.756	0.271	0.300
CHN	9.845	9.853	0.205	0.059
JPN	1.129	1.191	0.062	0.075
KOR	5.043	5.046	0.018	0.031
ROW	—	—	0.259	0.305

Note that we calibrate country i's breach probability of technologies from country n as

$$\phi_{in}(d_{in}^P, \xi_n) \;=\; (1-\xi_n)\,\phi_0\,\Big[1-\exp\big(1-(d_{in}^P)^{\kappa^\phi}\big)\Big],$$

so that the *country-specific* upper bound is

$$\lim_{d_{in}^P\to\infty}\phi_{in}(d_{in}^P, \xi_n) \;=\; (1-\xi_n)\,\phi_0.$$

[3]Estimates for the data are based on bilateral royalties between 2001–2020. Model coefficients are produced by simulating the Balanced Growth Path. The calibration adjusts κ^ϕ to match the coefficient on $\log(d^P - 1)$.

The last term, $1 - \exp\big(1 - (d^P)^{\kappa^\phi}\big)$, is increasing in d^P and converges to 1 as $d^P \to \infty$; hence κ^ϕ governs the *curvature* with which breach risk approaches its ceiling, but not the ceiling itself. Two parameters pin down the level: ϕ_0 is the asymptotic breach probability when there is *no* enforcement ($\xi_n = 0$) and geopolitical misalignment is arbitrarily large, while $\xi_n \in [0, 1]$ (IPR) linearly lowers the ceiling to $(1 - \xi_n)\phi_0$. Economically, geopolitical distance raises breach risk but cannot push it beyond the institutional limit implied by the destination's IPR; stronger IPR (higher ξ_n) lowers the maximum breach probability. This is consistent with the empirics: penalties from geopolitical misalignment are largest where IPR is weak and are muted where IPR is strong, while the distance elasticity shapes how quickly risk rises with misalignment.

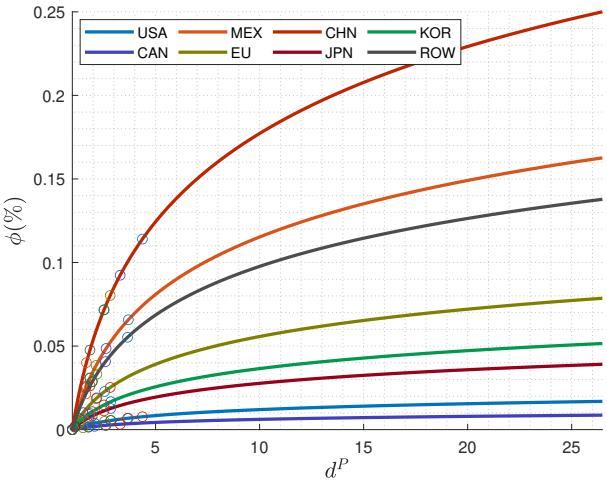


Figure 1: Breach hazard as a function of geopolitical distance with a destination-specific ceiling.

Notes: The curves plot $\phi_{in}(d^P, \xi_n) = (1 - \xi_n)\phi_0 \left[1 - \exp(1 - (d^P)^{\kappa^\phi})\right]$.

External Validation We assess the external validity of the calibrated model by comparing simulated outcomes to empirical counterparts along a set of untargeted moments. First, the correlation between model-implied TFP and the data is 0.983. The correlation between simulated and observed adoption probabilities is also very high at 0.996. Turning to innovation effort, the correlation between model and data for R&D expenditures as a share of world output is 0.808. Finally, for licensing activity, the correlation between simulated and observed log-royalty payments is 0.838. The first two correlations are particularly high because, even though we did not target the full transition path, we disciplined the BGP values. The strong fit for R&D effort and royalties further supports

the model's ability to reproduce the joint dynamics of innovation, adoption, and licensing flows.

Importantly, the geopolitics–royalty patterns and growth responses highlighted in the main analysis survive despite this underprediction.

It is also important to note that the coefficient on the interaction term $\log(d^P-1)\times$IPR in Table 7 is an untargeted moment. Although the calibration disciplined the coefficient on $\log(d^P - 1)$ directly, the interaction term was left free and is therefore an additional source of external validation.

5.2 Baseline transition to the BGP (USA–China)

We begin by documenting how the calibrated USA–China economy moves from the initial year to its BGP with no additional shocks. The six panels in Figure 2 report the objects we use as references for the counterfactuals: bilateral royalty rates, innovation effort as a share of world output, log consumption for each country, and the relative technology position.

Along the baseline, bilateral royalty rates rise at the beginning of the transition and then converge to a stable plateau. With ρ_{in} and $\phi(d_{in}^P)$ fixed, time variation in $\eta_{in,t}$ is entirely driven by the ratio $\Upsilon_{in,t}^{\text{Breach}}/\Upsilon_{in,t}$ in

$$\eta_{in,t} = \rho_{in}\Big[1 + \Upsilon_{in,t}^{\text{Breach}}/\Upsilon_{in,t}\Big].$$

As the economy scales up, the compliant profit stream $\Upsilon_{in,t}$ expands because adopters operate in a larger market and generate higher profits $\pi_{in,\tau}$ along the compliant path. The breach continuation value $\Upsilon_{in,t}^{\text{Breach}}$ also grows, but it is realized only after leakage and is therefore more heavily discounted. Early in the transition, the expected present value of future compliant licensing rises faster than the breach alternative. This increases the innovator's surplus in Nash bargaining and raises the negotiated royalty rate. Once the economy approaches its balanced growth path, both components grow at the common trend rate and their ratio stabilizes, yielding a constant long-run $\eta_{in,t}$. The early rise followed by a plateau therefore reflects a transition from a small-scale economy in which future rents are limited to a mature economy in which the value of compliant diffusion is fully capitalized into contracts.

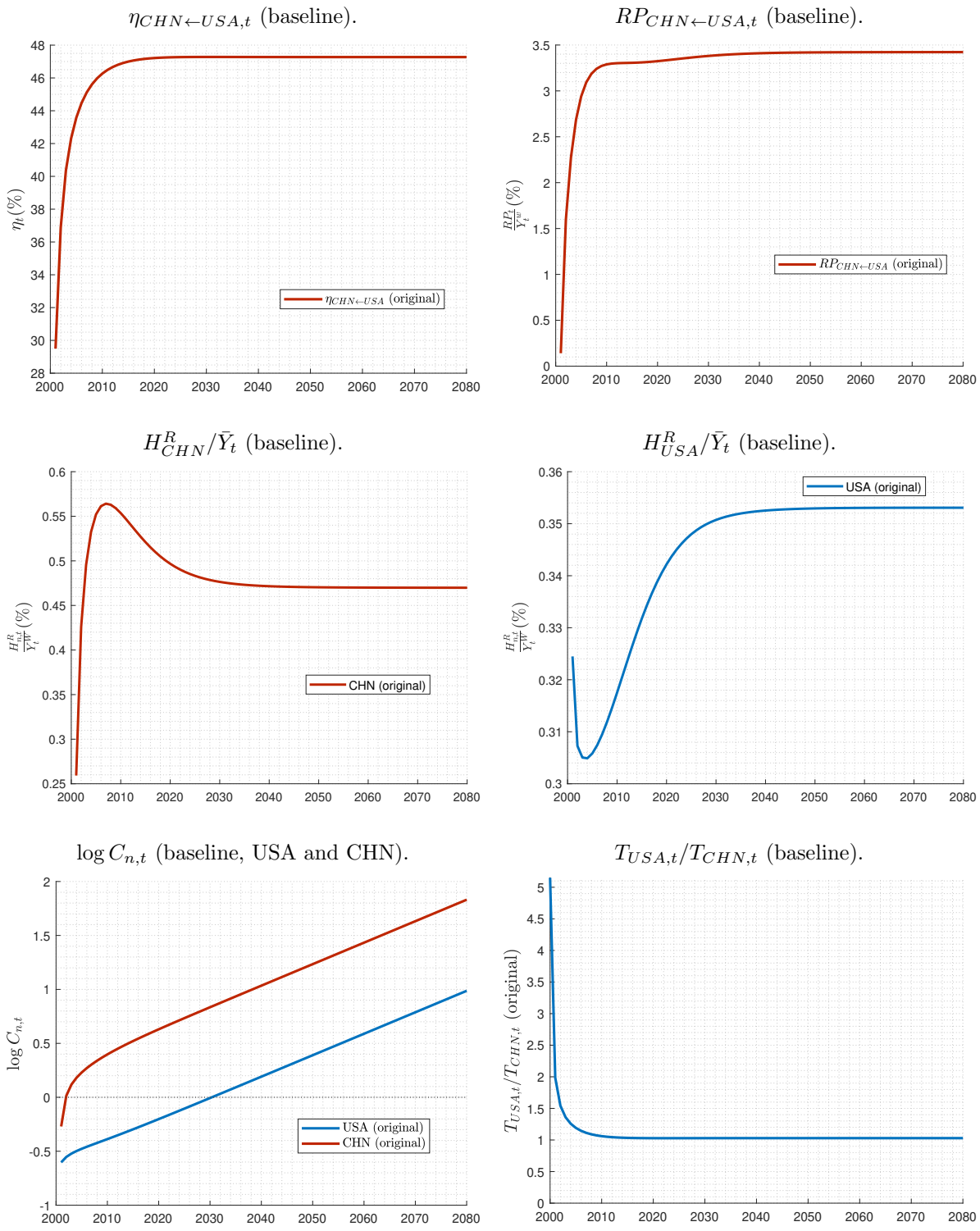


Figure 2: Baseline transition to the BGP: USA and China. Notes: Parameters and wedges are from the calibration.

Royalty payments $RP_{in,t}$ increase more strongly than royalty rates. This reflects the adoption margin. During the transition, the stock of adopted technologies expands rapidly and the mass of compliant contracts rises. Aggregate royalties therefore grow

through a quantity channel — more licensed technologies — in addition to the price channel embedded in $\eta_{in,t}$. As adoption slows near the BGP and the cohort structure stabilizes, royalty payments grow at the common trend and their share in world output converges.

Innovation effort displays asymmetric transitional dynamics. China's research intensity $H^R_{CHN,t}/\bar{Y}_t$ exhibits a hump-shaped path: rapid catch-up raises the marginal value of innovation early on, but as the technology gap narrows and adoption saturates, incentives revert toward their BGP level. In contrast, US research intensity rises monotonically and converges from below to its BGP. The United States benefits from the expanding global market for its ideas and from the increasing scale of compliant adoption abroad. Even though catch-up reduces relative technological distance, the absolute value of innovation remains high because expected diffusion volumes expand with world output.

Consumption grows smoothly in both countries. In logs, the paths are approximately linear, indicating convergence to a common balanced growth rate. Transitional differences in levels reflect initial technology gaps and the gradual repricing of licensing claims, but the staggered renewal structure of contracts prevents large front-loaded swings.

Finally, the relative technology position $T_{USA,t}/T_{CHN,t}$ declines early in the transition and then stabilizes above one. The initial compression reflects rapid Chinese catch-up driven by adoption and higher early R&D effort. Stabilization occurs once both countries settle into their BGP research intensities. The long-run outcome is a smaller but persistent US lead: catch-up is powerful but incomplete. The dynamics of royalties and innovation are consistent with this pattern. Early in the transition, rapid adoption and rising royalty rates amplify the flow of technology toward the follower; later, stationary adoption intensities and stable licensing terms preserve a constant technology gap.

5.3 Counterfactual: Bilateral US–China Fragmentation

We now study the counterfactual in which geopolitical distance between the United States and China rises permanently. Figures 3 report the transition dynamics. The dashed line denotes the baseline path toward the original BGP, while the solid line shows the new transition when the shock occurs in the first period.

The immediate adjustment in adoption is asymmetric because adoption investment is chosen based on the expected continuation value of using a foreign technology before

contract enforcement is realized. This continuation value reflects both enforcement risk and the effective market size associated with compliant licensing. China's adoption of US technologies, $\epsilon_{CHN \leftarrow USA}$, declines persistently relative to baseline as higher breach risk and reduced market access lower the compliant continuation value of foreign technologies. In the United States, there is a reallocation of innovation towards adoption, so adoption from china increases slightly.

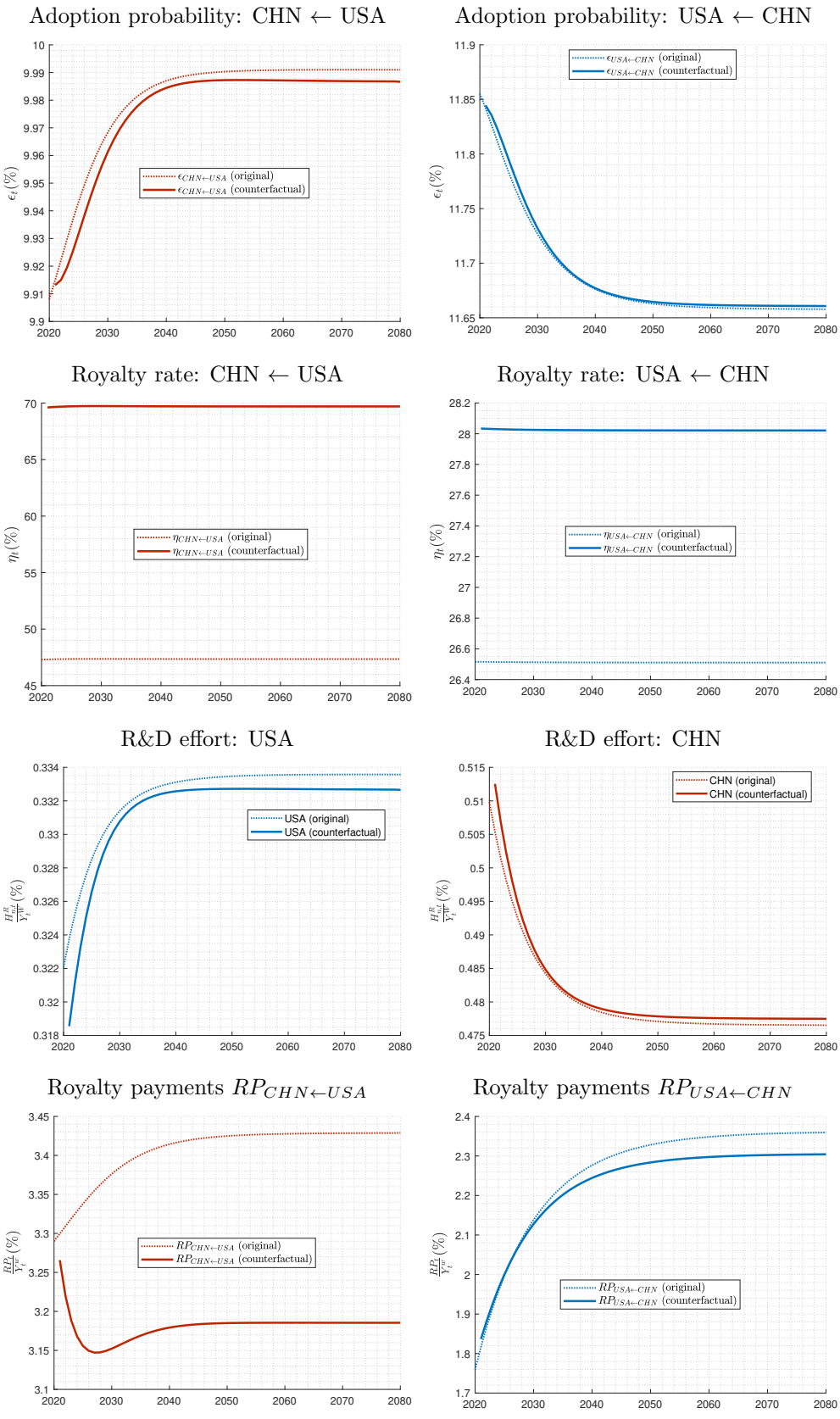
Royalty rates jump upward in both directions because innovators reprice breach risk under Nash bargaining. However, the response of aggregate royalty *payments* is not mechanically tied to the current royalty rate. Payments reflect the stock of legally paying technologies, that is, newly adopted cohorts and previously adopted cohorts whose contracts have not yet been breached, so they depend on both the flow of adoption and the survival of legacy contracts. Following the shock, higher breach risk reduces contract survival and shrinks the stock of compliant technologies over time. As a result, royalty payments can decline even as η rises, because the quantity of compliant uses falls and previously paying cohorts transition into the breach state. The transition is therefore characterized by contract repricing on impact and a gradual, quantity-driven decline in royalty payments as the compliant stock erodes.

The contraction in licensing feeds directly into innovation incentives and generates an asymmetric reallocation of research effort. US research intensity $H^R_{USA}/\bar{Y}$ lies below its baseline path throughout the transition. Lower compliant adoption reduces the expected value of licensing innovations and weakens R&D incentives in the US. In contrast, China's research intensity rises relative to baseline. Reduced access to foreign technologies raises the shadow value of domestic innovation and induces substitution away from adoption and toward internal R&D. The shock therefore reallocates innovation geographically: it compresses research in the leader while stimulating catch-up investment in the follower. Global innovation does not decline, but its location shifts.

These dynamics translate into a gradual erosion of relative technological leadership. The ratio T_{USA}/T_{CHN} falls below its baseline trajectory and stabilizes at a lower level. Fragmentation narrows the technology gap because it disproportionately reduces the value of exporting frontier technologies while increasing the incentive for domestic innovation in the follower.

Consumption paths follow from the adjustment in firm profits and innovation activity

Figure 3: Impulse responses for adoption, royalty rates, R&D, and royalty payments following a permanent increase in US–China geopolitical distance. Dotted lines denote the baseline transition to the original BGP; solid lines denote the counterfactual path with the shock in the first period.



induced by lower compliant adoption. Because households own all firms, profits from production and licensing enter directly into household income. The rise in geopolitical distance reduces cross-border adoption and lowers the scale at which frontier technologies are used internationally. Even though royalty rates rise through contract repricing, the decline in adoption quantities compresses the compliant continuation value of innovation and reduces profit income accruing to the leader economy. US consumption therefore lies below its baseline path throughout the transition.

In China, reduced foreign adoption raises the relative value of domestic innovation. Higher internal R&D expands the stock of locally owned varieties and shifts profit income toward Chinese households. This reallocation partially offsets the contraction in foreign adoption and supports consumption relative to baseline.

In the long run both economies converge to new balanced growth paths with a lower common growth rate. Fragmentation reduces compliant adoption, weakens the innovation block of the leader, and reallocates research activity toward the follower. Consumption adjusts through the resulting shift in profit flows and the lower BGP growth rate.

Figure 4 summarizes the welfare-relevant outcomes. Relative technology declines modestly and then stabilizes, while consumption deviations remain small but persistent.

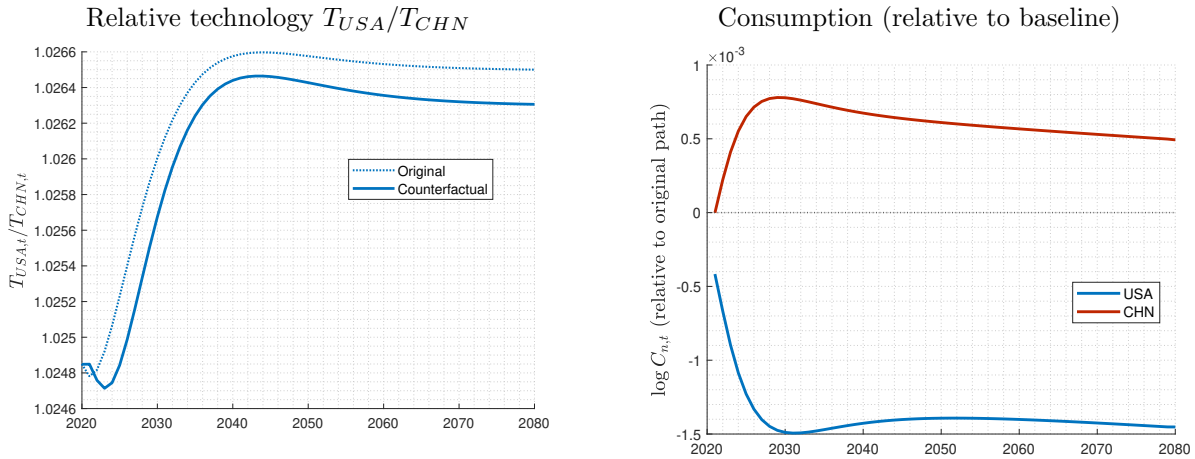


Figure 4: Welfare-relevant outcomes of a permanent increase in US–China geopolitical distance. Relative technology shows the erosion of US leadership, while consumption captures the asymmetric welfare costs for the US and China.

Mechanism The counterfactual exercises highlight a price–quantity decomposition of technology adoption. Geopolitical shocks operate through two margins: a bargaining channel that determines the contractual price of licensing and a market-size channel that

governs the scale of compliant adoption. Nash bargaining pins down the royalty share as a function of continuation values, so contract repricing responds to enforcement risk, while market access determines how much adoption occurs. Innovation incentives depend on the joint evolution of these margins.

The importance of this interaction becomes transparent in a fixed-η benchmark. When the royalty rate is held constant, the endogenous price margin is shut down and the equilibrium response to geopolitical distance is driven almost entirely by breach dynamics. Allowing or removing market-size effects then produces nearly identical transition paths. Market access changes the level of surplus available from adoption, but with a fixed sharing rule it does not materially alter innovation incentives. By contrast, when η is renegotiated through Nash bargaining, market size becomes first-order because it determines how strongly contract repricing translates into adoption and R&D responses. The Appendix reports the fixed-η and market-size decomposition experiments that isolate these forces.

Welfare and Global Spillovers. The bilateral USA–China fragmentation generates global spillovers through the reallocation of trade and technology flows. As the the US and China contract their licensing relationship, innovation rents are redistributed. The dominant effect is a shift of rents toward China.

Table 8 reports consumption-equivalent welfare changes. They measure the per-period consumption compensation required to make the consumer indifferent between remaining on the baseline transition path and switching to the path with higher geopolitical distance. The welfare effects of fragmentation are asymmetric across countries and become more pronounced under extreme decoupling. China is the only economy that experiences welfare gains in both counterfactuals. Reduced access to US technologies induces substitution toward domestic innovation and raises the share of innovation rents captured internally. This reallocation more than offsets the loss of foreign licensing revenues, generating a net welfare gain for China that nearly doubles under perfect decoupling. By contrast, the United States experiences the largest welfare loss. Lower royalty revenues and weaker foreign adoption compress innovation rents and reduce consumption along the transition. These losses intensify as geopolitical distance rises further. Third countries mostly incur small but negative welfare effects, reflecting reduced access to frontier

technologies and lower global innovation. At the global level, fragmentation lowers the balanced growth rate, with the decline becoming substantially larger under perfect decoupling.

Table 8: Welfare and Growth Effects of Geopolitical Fragmentation (consumption–equivalent changes, %)

$\%\Delta W_i^{eff}$	US–CHN Rivalry (ϕ double)	US–CHN Decouple ($d^P \to \infty$)
USA	-0.133	-0.276
CAN	-0.010	-0.032
MEX	-0.006	-0.020
EU	-0.010	-0.027
CHN	0.059	0.110
JPN	0.001	-0.001
KOR	-0.002	0.002
ROW	-0.008	-0.024
$\%\Delta g$	-0.017	-0.075

Notes: Each column corresponds to one counterfactual experiment. Positive values denote welfare or growth gains; negative values denote losses. Growth rates refer to changes in the BGP consumption growth rate.

6 Policy Application: Export Controls

The mechanism developed above describes how geopolitical shocks reshape innovation through contract pricing and adoption quantities. Export controls operate directly on this contractual margin by restricting legally enforceable rights to use technology. Governments therefore intervene where private contracting determines the scale and direction of diffusion. We use the model as a laboratory to study how such interventions interact with the price–quantity forces identified above and how optimal policy depends on government objectives. The purpose of this section is not to reinterpret the mechanism, but to analyze its policy implications when states actively shape the contracting environment.

6.1 Optimal Export Control Policy

We consider the conditions under which a government may choose to impose unilateral export controls when geopolitical distance rises. This question is motivated by recent policy debates in which governments explicitly weigh economic efficiency against strategic

technological leadership, particularly in sectors such as semiconductors, advanced computing, and AI. To capture this tension, we embed national security considerations into the government's objective function by allowing welfare to depend not only on consumption, but also on relative technological leadership. This extension allows us to study how policy choices interact with the endogenous allocation of innovation generated by the licensing mechanism.

Specifically, we model export controls as a policy wedge that directly restricts cross-border adoption. Formally, an export-control intervention scales the maximum adoption intensity by a policy factor $\chi_{in} \in [0, 1]$,

$$\bar{\epsilon}_{in}^{policy} = (1 - \chi_{in})\, \bar{\epsilon}_{in}. \tag{40}$$

A higher value of χ_{in} represents tighter restrictions on technology transfers from country n to country i. The policy operates exclusively through this adoption constraint: it reduces the feasible intensity of foreign technology implementation without directly altering innovation productivity or licensing technology. All other equilibrium variables adjust endogenously to the change in adoption opportunities.

Consumption-based welfare function We first consider a benchmark government that values only lifetime household consumption. The government evaluates unilateral export controls taking the private-sector equilibrium as given: firms optimally reprice licensing contracts and adjust adoption in response to geopolitical shocks, while policy operates solely through the export-control wedge χ.

Under this benchmark, higher export controls reduce consumption-equivalent welfare in the United States. Figure 5 shows that US welfare is monotonically decreasing in χ. Even though royalty rates rise through contract repricing, tighter controls compress compliant adoption and lower the scale at which US-owned technologies are used abroad. Because households own firms, this contraction reduces profit income and therefore consumption. The optimal policy under a pure consumption objective is $\chi = 0$.

China experiences a much larger welfare loss as χ rises, reflecting the direct reduction in access to frontier technologies. Welfare changes in third regions are comparatively small. The figure therefore highlights that export controls redistribute consumption primarily across the bilateral relationship rather than generating large global gains.

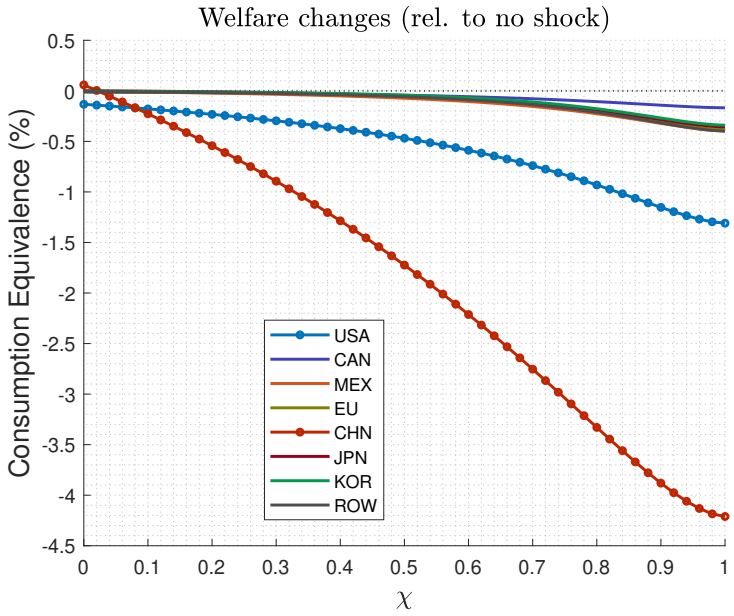


Figure 5: Consumption-equivalent welfare effects of export controls (χ) under a consumption-based objective. Higher χ denotes tighter US export restrictions on China.

The left panel of Figure 6 shows that tighter US export controls monotonically reduce the balanced-growth-path rate. The economic intuition is that restricting China's access to US technologies compresses the effective market in which frontier ideas can be diffused. Because innovation incentives depend on the expected scale of licensing, the contraction in compliant adoption lowers R&D effort and shifts the economy to a lower-growth equilibrium. In Perron–Frobenius terms, the policy reduces the dominant eigenvalue of the global adoption matrix that governs idea propagation, and hence lowers the common growth rate of the system.

The right panel shows that even a unilateral disruption reshapes the global allocation of innovation. Preventing China from adopting US technologies increases China's reliance on domestic innovation while leaving the reverse channel intact. Because each country's technology stock reflects both domestic research and foreign adoption, this asymmetric restriction propagates through the world diffusion network. Countries not directly targeted by policy still experience reweighting of their technology stocks through general equilibrium spillovers. In the new stationary allocation, the United States gains relative weight while China loses weight in world technology, reflecting the higher efficiency of US innovation.

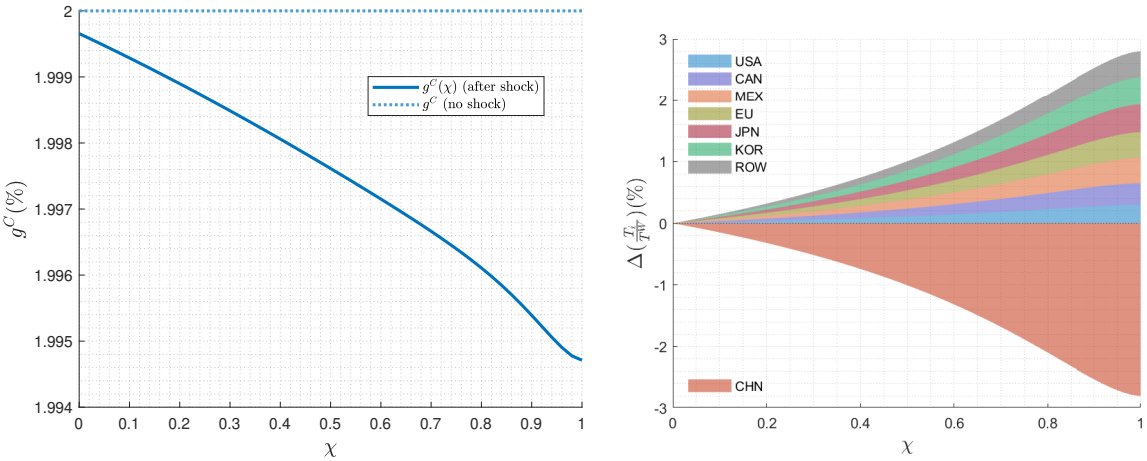


Figure 6: Changes in BGP growth rate and T distribution

Welfare with National Security Concerns We next allow the government to place weight on relative technological leadership in addition to consumption. The government maximizes

$$W_{US}^{A} = \sum_{t=0}^{\infty} \beta^t \left[(1 - \gamma_{US,CHN}) \cdot u(C_{US,t}) + \gamma_{US,CHN} \cdot g\left(\frac{T_{US,t}}{T_{US,t} + T_{CHN,t}} \right) \right], \tag{41}$$

where $g(\cdot)$ is increasing in the US share of bilateral technological leadership and $\gamma_{US,CHN}$ measures the weight placed on national security. A decline in the relative technology ratio reduces welfare even if consumption rises. The government may therefore accept lower consumption in exchange for preserving technological advantage.

With this augmented objective, export controls affect welfare through two margins. Tighter controls reduce consumption by lowering compliant adoption and profit income, but they also slow the rival's technological catch-up. The optimal policy balances these forces.

We study the US choice of unilateral export-control intensity $\chi \in [0, 1]$ when geopolitical rivalry increases under three retaliation environments: (i) no retaliation, (ii) certain retaliation, and (iii) retaliation with a probability that rises in χ. For each χ we solve the perfect-foresight transition and evaluate consumption-equivalent welfare.

Figure 8 reports the optimal control χ^* as a function of $\gamma_{US,CHN}$. Without retaliation, the optimal policy quickly moves toward a corner solution: once the security motive is sufficiently strong, the government chooses a very high control intensity.

Figure 7 illustrates the augmented welfare decomposition used to evaluate optimal export control policy in the absence of retaliation. Aggregate welfare is defined as

$$W^A = (1-\gamma)W^C + \gamma W^T,$$

where W^C denotes discounted lifetime utility from consumption and W^T denotes discounted lifetime utility from the relative technology position. The parameter $\gamma \in [0,1]$ captures the weight the government places on technological leadership relative to consumption.

The shaded regions in the figure visualize this decomposition. The blue area corresponds to $(1-\gamma)W^C$, while the grey area represents γW^T. The left panel considers the benchmark case $\gamma = 0$, in which welfare coincides with consumption utility. In this case $W^A = W^C$ declines monotonically as export controls tighten, consistent with the consumption-equivalent losses shown earlier: restricting adoption compresses diffusion and lowers growth.

The right panel considers the opposite extreme $\gamma = 1$, in which the government values only relative technological leadership. Here $W^A = W^T$ increases monotonically in the policy intensity χ. Stronger export controls widen the domestic technology gap and raise leadership utility, even though they reduce global diffusion.

For intermediate values of γ, augmented welfare reflects a tradeoff between these forces. The middle panel stacks the consumption and leadership components. The dotted vertical line at $\chi \approx 0.45$ marks the optimal policy when $\gamma = 0.1$. At this point the marginal gain from strengthening technological leadership equals the marginal consumption loss. As γ rises, the optimal export control becomes more stringent, reflecting the increasing weight placed on relative innovation advantage.

With uncertain retaliation, the optimal control is interior and increasing in $\gamma_{US,CHN}$: higher security concerns raise the marginal benefit of restriction, but the rising risk of retaliation makes large controls increasingly costly. With certain retaliation, the optimal policy remains zero for low security weights and becomes positive only when the leadership motive dominates the consumption loss.

These policy results are a direct implication of the core price–quantity mechanism developed in the model. Export controls operate through the same adoption and contract-pricing margins that govern private responses to geopolitical shocks. From a pure consumption-

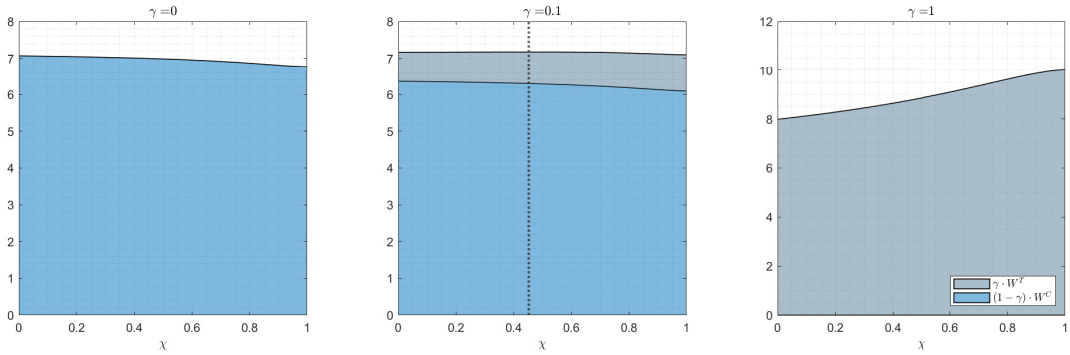


Figure 7: Augmented Welfare Decomposition under Unilateral Export Controls

Notes: The figure plots augmented welfare as a function of export control intensity χ. Blue (grey) shading shows the consumption (leadership) component. Panels correspond to different values of γ; the dotted line marks the optimal policy. Welfare is normalized relative to the no-policy baseline.

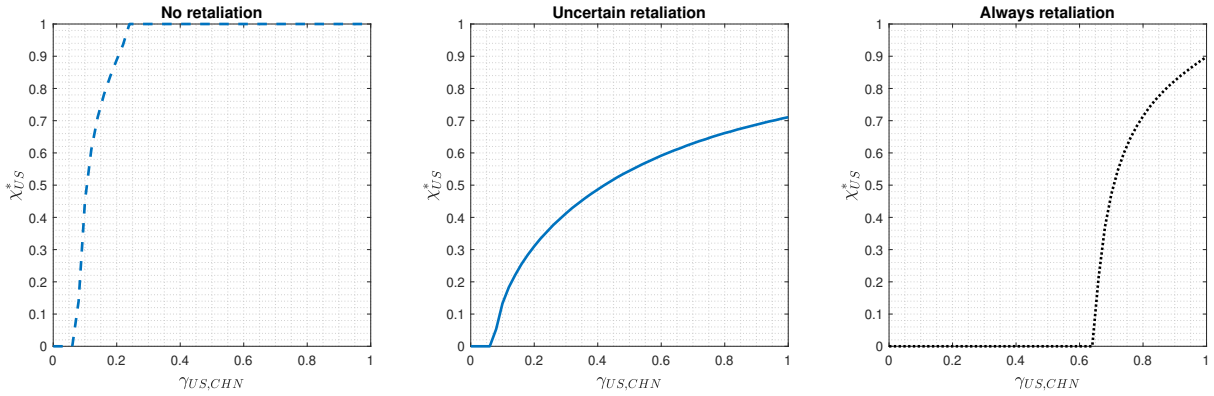


Figure 8: Optimal US export-control intensity χ^*_{USA} as a function of the national-security weight $\gamma_{USA,CHN}$ under three retaliation environments.

efficiency perspective, the mechanism provides no role for policy intervention: tighter controls reduce compliant adoption and lower welfare. Policy intervention emerges only when governments place weight on objectives beyond consumption, such as relative technological leadership.

The policy analysis therefore illustrates that strategic technology restrictions arise from government preferences rather than from an inefficiency in private contracting, while the underlying economic forces remain those emphasized in the core model.

7 Final Remarks

This paper studies how geopolitical shocks reshape innovation through the contractual structure of cross-border technology adoption. Many forms of diffusion occur outside formal licensing, but licensing is the margin where prices are explicitly set and innovation rents are allocated. Recent policy interventions such as export controls, licensing restrictions, and investment screening, operate directly on these contractual margins, and the data show that royalty flows are more sensitive than goods trade to geopolitical distance, especially where enforcement is weak. This makes licensing a natural laboratory for studying how political risk feeds back into innovation incentives.

Our quantitative results show that fragmentation reallocates innovation across countries and lowers BGP growth rates by compressing compliant adoption. The same price–quantity mechanism governs the welfare consequences of policy interventions. Under a pure consumption objective there is no role for export controls; intervention arises only when governments value technological leadership in addition to efficiency.

More broadly, when innovation is traded through enforceable contracts, geopolitical frictions propagate through pricing and adoption decisions rather than through trade volumes alone. Understanding global growth under fragmentation therefore requires tracking how political risk reshapes the market for technology itself.

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A Appendix

A.1 Data

Data Sources The empirical analysis combines multiple international datasets, harmonized at the bilateral-year level. The dataset contains 42 countries and a category called ROW (Rest of the World). The ROW category aggregates the following variables for all other countries in the dataset. The 41 countries were identified from the World Input Output Database (WIOD).Vietnam was added later. The key variables and their sources are:

- **Trade Flows**: Annual bilateral trade in current thousand USD, from the BACI database maintained by CEPII. BACI reconciles export and import declarations in UN Comtrade to provide consistent and symmetric trade flows. Here, the bilateral *tradeflow_baci* ranges from 2000 to 2021. The initially unbalanced dataset was subsequently balanced. Finally, all the NAs were replaced by 0.

- **Royalties**: Charges for the use of intellectual property (millions USD), from OECD's Balanced Trade in Services or BaTIS. These cover payments between residents and non-residents for the authorized use of intellectual property, including patents, trademarks, and industrial processes. Here, the bilateral balanced export data was used from the year 2005 till 2021.

- **Geopolitical Distance**: Bilateral ideal-point distance (IPD) based on United Nations General Assembly roll-call voting, following the methodology of Bailey, Strezhnev, and Voeten (2017). The scores are derived from a dynamic ordinal item-response model and reflect long-run foreign policy alignment. Here, *Idealpointall* is used, which is based on all votes, including votes on paragraphs and amendments. The *Idealpointall* measure contains the ideal-point distance for each country. The ideal-point for the country pair is subtracted, and its absolute value is taken. Then, the log of the difference is used. Here, the IPD data ranges from the year 2000 till 2021.

  To ensure robustness, multiple variations of the ideal-points were used in regression models. These include: *idealpointfp* from Bailey, Strezhnev, and Voeten (2017), which calculates the ideal-point based on the final votes at the United Nations;

ipd_all_full from Airaud et al. (2025), which estimates IPD using the full sample of UN votes; *ipd_econ_full* from Airaud et al. (2025), which estimates IPD using the subset of only economic votes; and finally, *ipd_all_short*, which estimates IPD from the sample of all UN votes after 1991. The regression results are consistent across all the IPD measures, ensuring robustness.

- **IPR Protection**: Protection of Intellectual Property Rights (IPR) (0–10 scale) is a component of the International Property Rights Index, published annually by the Property Rights Alliance. The data captures citizens' perspectives on the protection of intellectual property in their country. Here, the scale was normalized by dividing it by 10. Here, the IPR Protection data ranges from the year 2007 till 2021.

  Similar to geopolitical distance, there were multiple variations of protection of intellectual property rights that were used in the regression models to ensure robustness of the results. These include: *International Property Rights Index*; *Intellectual Property Rights Subindex*, which includes protection of intellectual property rights as one of its factors. *Patent Protection* was used as one of the variations; however, the index had more NAs than all other indices. Finally, *Protection of Intellectual Property Rights* was chosen as in the final regression model it was directly related to the aim of the paper. The regression results are consistent across all IPR measures, ensuring robustness.

- **Geographic Distance, Common Language, Contiguity, and Trade Agreements**: Data sourced from CEPII's Gravity dataset. Geographic distance is measured as the great-circle distance between capital cities, with log distance used in the regression. Contiguity indicates whether countries share a land border. Trade agreement participation covers common membership in FTAs or the WTO. Common language indicates whether the countries share a common primary or official language. Like trade flow data above, the above variables ranges from 2000 to 2021.

Table 9 reports descriptive statistics for the variables of interest for the period 2007-2021 when the sample is restricted to 44 countries.

Identifying Country-Pairs Driving Positive Geopolitical Impact on Royalties
A natural concern is whether the positive coefficient on geopolitical distance in our base-

Table 9: Descriptive Statistics of Key Variables

	mean	sd	min	p25	p50	p75	max	count
IPR Index	0.70	0.18	0.00	0.55	0.69	0.89	1.00	27,090
Log Geopolitical Distance	-1.06	1.46	-12.76	-1.85	-0.86	0.14	1.33	27,090
Royalties (Mill. USD)	183.22	1045.71	0.00	0.56	5.43	46.49	56376.05	27,090
Trade Flow (Mill. USD)	7170.37	27800.00	0.00	116.11	769.05	3896.19	775000.00	27,090

line regressions is driven by tax havens that attract royalty payments for fiscal rather than technological reasons. To address this, we re-estimate the specification excluding common tax havens. Consistent with the idea that profit-shifting inflates our baseline results, the coefficient on geopolitical distance falls markedly in magnitude, although it remains positive and statistically significant. This suggests that part of the raw positive relationship between geopolitical distance and royalty flows is explained by the disproportionate role of jurisdictions such as Ireland, the Netherlands, and Switzerland, which serve as major hubs for royalty routing despite their geopolitical distance from the United States.

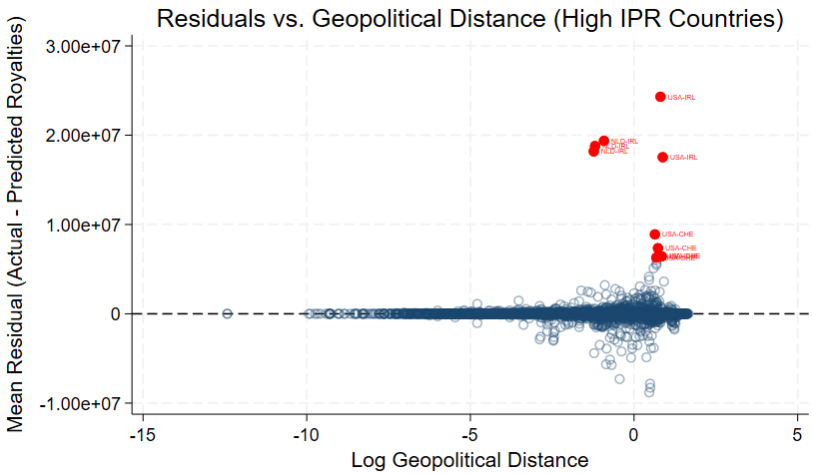


Figure 9: Residuals vs. Geopolitical Distance for High-IPR Country-Pairs

When we examine residuals from this restricted regression, the largest positive outliers correspond to flows between highly innovative economies, in particular the United States and the European Union, and the United States and Japan. In these cases, royalty payments are underpredicted by geopolitical distance alone. This pattern highlights that, once profit-shifting destinations are excluded, the positive association between distance and royalties is partly capturing the fact that technologically advanced economies engage in disproportionately licensing with one another, even across large geopolitical

Table 10: List of Countries

ISO 3 Code	Country Name
AUS	Australia
AUT	Austria
BEL	Belgium
BGR	Bulgaria
BRA	Brazil
CAN	Canada
CHE	Switzerland
CHN	China
CYP	Cyprus
CZE	Czech Republic
DEU	Germany
DNK	Denmark
ESP	Spain
EST	Estonia
FIN	Finland
FRA	France
GBR	Great Britain
GRC	Greece
HRV	Croatia
HUN	Hungary
IDN	Indonesia
IND	India
IRL	Ireland
ITA	Italy
JPN	Japan
KOR	South Korea
LTU	Lithuania
LUX	Luxembourg
LVA	Latvia
MEX	Mexico
MLT	Malta
NLD	Netherlands
NOR	Norway
POL	Poland
PRT	Portugal
ROW	Rest of the World
RUS	Russian Federation
SVK	Slovakia
SVN	Slovenia
SWE	Sweden
TUR	Turkey
USA	United States of America
VNM	Vietnam

divides. In other words, geopolitical distance reduces the likelihood of licensing in weaker institutional environments, but among advanced economies with strong IPR, innovation intensity dominates, sustaining large royalty flows that are not fully explained by our baseline measure of distance. Figure 10 visualizes the residuals from our royalty regression without the interaction term. The scatter plot highlights country-pairs with the largest positive residuals—cases where observed royalty flows substantially exceed the values predicted based on geopolitical distance and other controls. Pairs such as USA–Ireland, Netherlands–Ireland, and USA–Switzerland stand out prominently. These pairs register exceptionally high residuals despite varying levels of geopolitical distance, suggesting that other factors, such as favorable institutional environments for intellectual property and corporate taxation, may be at play.

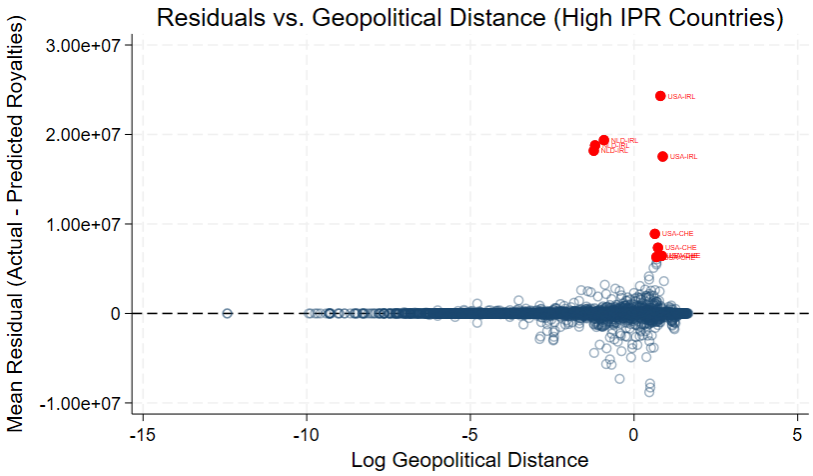


Figure 10: Residuals vs. Geopolitical Distance for High-IPR Country-Pairs

These results suggest that the initial positive coefficient on geopolitical distance in the absence of IPR controls is partly driven by a narrow set of country-pairs with exceptional institutional or fiscal characteristics.

.1 Stationary system

The trick is that are two layers of normalization: normalize by $W_{M,t}$ for static block and by $T_{M,t}^{\frac{1}{\sigma-1}}$ for dynamic block.

Resource constraints:

$$\hat{C}_{n,t} = \hat{Y}_{n,t} - \hat{H}^R_{n,t} - \hat{H}^A_{n,t} \tag{42}$$

where $\hat{X}_{n,t} \equiv \frac{X_{n,t}}{T_{M,t}^{\frac{1}{\sigma-1}}}$.

Price indices:

$$\hat{P}_{n,t}^{1-\sigma} = \sum_{i=1}^{M} \Omega_{it}^{\sigma-1} \hat{T}_{i,t} (\bar{m}\hat{\omega}_{i,t} d_{ni}(1+\tau_{ni,t}))^{1-\sigma}$$

where $\hat{X}_{it} \equiv \frac{W_{i,t}}{W_{M,t}}$. $\hat{T}_{it} \equiv \frac{T_{i,t}}{T_{M,t}}$ and $\hat{P}_{n,t} \equiv \frac{P_{i,t} T_M^{\frac{1}{\sigma-1}}}{W_{M,t}}$.

Trade shares (This is stationary without normalization):

$$s_{in,t} = \frac{\Omega_{nt}^{\sigma-1} \hat{T}_{n,t} (\bar{m}\hat{\omega}_{n,t} d_{in}(1+\tau_{in,t}))^{1-\sigma}}{\hat{P}_{i,t}^{1-\sigma}}, \tag{43}$$

We stationarize the value functions by rewriting

$$\hat{Q}_{n,t} \equiv \frac{T_{n,t} Q_{n,t}}{W_{M,t}}$$

where $Q = V$, V^{Innov}, V^{Adopt}, V^{Breach}, J^{Innov} and J^{Adopt}.

And the value of innovation is:

$$\hat{V}_{n,t} \equiv \sum_{i=1}^{M} \hat{J}_{in,t}^{innov} \frac{\hat{T}_{n,t}}{\hat{T}_{i,t}} \tag{44}$$

Profits of all firms:

$$\hat{\Pi}_{n,t} \equiv \frac{\Pi_{n,t}}{W_{M,t}} = \bar{m}\hat{\omega}_{n,t} L_n \tag{45}$$

The value of contract breach:

$$\hat{V}_{in,t}^{Breach} = \bar{m}\hat{\omega}_{i,t} L_i + \frac{\hat{V}_{in,t+1}^{Breach}}{R_t} \frac{\hat{P}_{i,t}}{\hat{P}_{i,t+1}} \frac{(1+g_{M,t})^{\frac{1}{\sigma-1}}}{1+g_{i,t}^T} \tag{46}$$

where $g_{M,t} \equiv \frac{T_{M,t+1}}{T_{M,t}} - 1$, and $g_{T,i,t} \equiv \frac{\hat{T}_{i,t+1}}{\hat{T}_{i,t}}(1+g_{M,t}) - 1$.

The value of adopted innovation to inventor:

$$\hat{V}_{in,t}^{Innov} = \eta_{in}\bar{m}\hat{\omega}_{i,t} L_i + (1-\phi(d_{in}^P)) \frac{\hat{V}_{in,t+1}^{Innov}}{R_t} \frac{\hat{P}_{i,t}}{\hat{P}_{i,t+1}} \frac{(1+g_{M,t})^{\frac{1}{\sigma-1}}}{1+g_{i,t}^T} \tag{47}$$

The value of adopted innovation to adopter:

$$\hat{V}_{in,t}^{Adopt} = (1-\eta_{in})\bar{m}\hat{\omega}_{i,t}L_i + \frac{(1-\phi(d_{in}^P))\hat{V}_{in,t+1}^{Adopt} + \phi(d_{in}^P)\hat{V}_{in,t+1}^{Breach}}{R_t}\frac{\hat{P}_{i,t}}{\hat{P}_{i,t+1}}\frac{(1+g_{M,t})^{\frac{1}{\sigma-1}}}{1+g_{i,t}^T} \tag{48}$$

The value of unadopted innovation to inventor:

$$\hat{J}_{in,t}^{Innov} = \frac{1}{R_t}\frac{\hat{P}_{i,t}}{\hat{P}_{i,t+1}}\left[\epsilon_{in,t}\hat{V}_{in,t+1}^{Innov} + (1-\epsilon_{in,t})\hat{J}_{in,t+1}^{Innov}\right]\frac{(1+g_{M,t})^{\frac{1}{\sigma-1}}}{1+g_{i,t}^T} \tag{49}$$

The value of unadopted innovation to adopter:

$$\hat{J}_{in,t}^{Adopt} = \frac{1}{R_t}\frac{\hat{P}_{i,t}}{\hat{P}_{i,t+1}}\left[(1-\beta_a)\epsilon_{in,t}\hat{V}_{in,t+1}^{Adopt} + (1-\epsilon_{in,t}+\beta_a\epsilon_{in,t})\hat{J}_{in,t+1}^{Adopt}\right]\frac{(1+g_{M,t})^{\frac{1}{\sigma-1}}}{1+g_{i,t}^T} \tag{50}$$

.2 Setup of skipping royalty payments instead of complete contract breach

.2.1 Value Functions and Licensing agreements

The value of an innovation from n which is successfully adopted by country i is

$$V_{in,t}^{innov} = (1-\phi(d_{in}^P))\eta_{in,t}\pi_{in,t} + \frac{1}{R_t}\frac{P_{i,t}}{P_{i,t+1}}V_{in,t+1}^{inno} \tag{51}$$

where $\eta_{in,t}$ is the profit sharing according to the licensing agreement and $\phi(d_{in,t}^P)$ is the probability that the adopter **skips** the royalty payment. This is an increasing function of the geopolitical distance. In case of the breach of contract, the value attributed to innovator is 0.

The value of an innovation form country n which has not been adopted in country i is

$$J_{in,t}^{innov} = \frac{1}{R_t}\frac{P_{i,t}}{P_{i,t+1}}\left[\epsilon_{in,t}V_{in,t+1}^{innov} + (1-\epsilon_{in,t})J_{in,t+1}^{innov}\right] \tag{52}$$

The value of successful adopter is

$$V_{in,t}^{adopt} = \left[(1-\phi(d_{in}^P))(1-\eta_{in,t}) + \phi(d_{in}^P)\right]\pi_{in,t} + \frac{1}{R_t}\frac{P_{i,t}}{P_{i,t+1}}V_{in,t+1}^{adopt} \tag{53}$$

The value of to-be-adopted innovation is

$$J_{in,t}^{adopt} = -P_{it}h_{in,t}^{a} + \frac{1}{R_t}\frac{P_{i,t}}{P_{i,t+1}}\left[\epsilon_{in,t}V_{in,t+1}^{adopt} + (1-\epsilon_{in,t})J_{in,t+1}^{adopt}\right] \tag{54}$$

The total value of an innovation from country n

$$V_{n,t} = \sum_{i=1}^{N} J_{in,t}^{innov} \tag{55}$$

.2.2 Royalty Fee

The total surplus value of adoption equals to stream of profits created

$$W_{in,t} = \pi_{in,t} + \frac{1}{R_t}\frac{P_{i,t}}{P_{i,t+1}}W_{in,t+1} \tag{56}$$

However, with the possibility of a breach of contract, innovator and adopter negotiate on η_{in} to maximize

$$\left[V_{in,t}^{innov}\right]^{\rho_{in}}\left[V_{in,t}^{adopt}\right]^{1-\rho_{in}} \tag{57}$$

Nash bargaining implies that[4]:

$$\eta_{in} = \frac{\rho_{in}}{1-\phi(d_{in}^{P})} \tag{58}$$

A Technology Adoption

Let A_t denote the stock of technologies adopted at time t. These technologies come from two sources: new technologies that arrive between periods $t-1$ and t, and previously legitimate technologies that have not yet been imitated. We define A_t^L as the stock of legitimate technologies at time t that generate royalty revenue.

The dynamics of technology adoption and imitation are governed by the following parameters:

- $\phi_t \in [0,1]$: The probability that a legitimate technology is imitated after one period

[4]If we assume adopter breaches the contract (terminates the payment, instead of skipping one), η_{in} would be smaller than $\frac{\rho_{in}}{1-\phi}$ because $V_{in,t}^{inno} \leq W_{in,t}$ and $V_{in,t}^{adopt} \leq W_{in,t}$. Hence, it would induce even less incentives to adopt.

- η_t: The royalty fee applied to legitimate technologies
- π_t: The profit generated by each technology
- T_t: The total number of available technologies in the market

A.1 Evolution of Legitimate Technologies

The stock of legitimate technologies evolves according to:

$$A_t^L = (A_t - A_{t-1}) + (1 - \phi_t)A_{t-1}^L \tag{59}$$

This equation captures two components:

- $(A_t - A_{t-1})$: Newly adopted technologies between periods $t-1$ and t
- $(1 - \phi_t)A_{t-1}^L$: Previously legitimate technologies that remain unimitated

A.2 Royalty Revenue Generation

The total royalty revenue generated at time t is given by:

$$RP_t = \eta_t \frac{A_t - A_{t-1}}{T_t}\pi_t + \eta_t(1 - \phi_t)A_{t-1}^L/T_t \tag{60}$$

This expression consists of two terms:

- $\eta_t \frac{A_t - A_{t-1}}{T_t}\pi_t$: Royalty revenue from newly adopted technologies, where $\frac{A_t - A_{t-1}}{T_t}$ represents the fraction of new technologies relative to all available ones
- $\eta_t(1-\phi_t)A_{t-1}^L$: Royalty revenue from previously legitimate technologies that remain protected from imitation

A.3 Balanced Growth Path Analysis with Explicit Treatment of Past Technologies

On a balanced growth path (BGP), the technology stock grows at a constant rate g_A, defined as:

$$g_A = \frac{A_t - A_{t-1}}{A_{t-1}} \tag{61}$$

This implies:

$$A_t = (1 + g_A)A_{t-1} \tag{62}$$

$$A_{t-1} = \frac{A_t}{1 + g_A} \tag{63}$$

For any time period $t - j$:

$$A_{t-j} = \frac{A_t}{(1 + g_A)^j} \tag{64}$$

Additionally, the ratio of adopted technologies to total available technologies is constant:

$$\frac{A_t}{T_t} = \alpha \tag{65}$$

Therefore:

$$T_t = \frac{A_t}{\alpha} \tag{66}$$

$$T_{t-j} = \frac{A_{t-j}}{\alpha} = \frac{A_t}{\alpha(1 + g_A)^j} = \frac{T_t}{(1 + g_A)^j} \tag{67}$$

A.3.1 Explicit Derivation of Legitimate Technologies

The stock of legitimate technologies at time t consists of technologies from all past periods that have not been imitated. For a technology introduced in period $t - j$, the probability it remains legitimate at time t is $(1 - \phi)^j$.

The flow of new technologies in period $t-j$ is:

$$A_{t-j} - A_{t-j-1} = g_A A_{t-j-1} = \frac{g_A A_t}{(1+g_A)^{j+1}} \tag{68}$$

Therefore, the stock of legitimate technologies at time t is the sum of all past technology flows, each adjusted by its probability of remaining legitimate:

$$\begin{aligned}
A_t^L &= (A_t - A_{t-1}) + (1-\phi)(A_{t-1} - A_{t-2}) + (1-\phi)^2(A_{t-2} - A_{t-3}) + \dots && (69)\\
&= \sum_{j=0}^{\infty}(1-\phi)^j(A_{t-j} - A_{t-j-1}) && (70)\\
&= \sum_{j=0}^{\infty}(1-\phi)^j \frac{g_A A_t}{(1+g_A)^{j+1}} && (71)\\
&= g_A A_t \sum_{j=0}^{\infty} \frac{(1-\phi)^j}{(1+g_A)^{j+1}} && (72)\\
&= \frac{g_A A_t}{1+g_A} \sum_{j=0}^{\infty} \left(\frac{1-\phi}{1+g_A}\right)^j && (73)
\end{aligned}$$

This is a geometric series with ratio $r = \frac{1-\phi}{1+g_A}$. Since $0 < \phi < 1$ and $g_A > 0$, we have $0 < r < 1$, so the series converges to $\frac{1}{1-r}$:

$$\begin{aligned}
A_t^L &= \frac{g_A A_t}{1+g_A} \frac{1}{1 - \frac{1-\phi}{1+g_A}} && (74)\\
&= \frac{g_A A_t}{1+g_A} \frac{1+g_A}{1+g_A-(1-\phi)} && (75)\\
&= \frac{g_A A_t}{1+g_A} \frac{1+g_A}{\phi+g_A} && (76)\\
&= \frac{g_A A_t (1+g_A)}{(1+g_A)(\phi+g_A)} && (77)\\
&= \frac{g_A A_t}{\phi+g_A} && (78)
\end{aligned}$$

Similarly, for the previous period:

$$\begin{aligned}
A_{t-1}^L &= \frac{g_A A_{t-1}}{\phi+g_A} && (79)\\
&= \frac{g_A \frac{A_t}{1+g_A}}{\phi+g_A} && (80)\\
&= \frac{g_A A_t}{(\phi+g_A)(1+g_A)} && (81)
\end{aligned}$$

A.3.2 BGP Royalty Revenue

The royalty revenue formula on the balanced growth path with A_{t-1}^L divided by T_t is:

$$\text{Royalty Revenue}_t = \eta \frac{A_t - A_{t-1}}{T_t}\pi + \eta(1-\phi)\frac{A_{t-1}^L}{T_t}\pi \tag{82}$$

Substituting our expressions:

$$\text{Royalty Revenue}_t = \eta \frac{g_A A_{t-1}}{\frac{A_t}{\alpha}}\pi + \eta(1-\phi)\frac{\frac{g_A A_t}{(\phi+g_A)(1+g_A)}}{\frac{A_t}{\alpha}}\pi \tag{83}$$

$$= \eta \frac{g_A \frac{A_t}{1+g_A}}{\frac{A_t}{\alpha}}\pi + \eta(1-\phi)\frac{g_A A_t}{(\phi+g_A)(1+g_A)}\frac{\alpha}{A_t}\pi \tag{84}$$

$$= \eta \frac{g_A \alpha}{1+g_A}\pi + \eta(1-\phi)\frac{g_A \alpha}{(\phi+g_A)(1+g_A)}\pi \tag{85}$$

Factoring out the common terms:

$$\text{Royalty Revenue}_t = \eta\alpha\pi g_A \left[\frac{1}{1+g_A} + \frac{1-\phi}{(\phi+g_A)(1+g_A)}\right] \tag{86}$$

To simplify the expression inside the brackets, we need to find a common denominator:

$$\frac{1}{1+g_A} + \frac{1-\phi}{(\phi+g_A)(1+g_A)} = \frac{\phi+g_A}{(\phi+g_A)(1+g_A)} + \frac{1-\phi}{(\phi+g_A)(1+g_A)} \tag{87}$$

$$= \frac{\phi+g_A+1-\phi}{(\phi+g_A)(1+g_A)} \tag{88}$$

$$= \frac{1+g_A}{(\phi+g_A)(1+g_A)} \tag{89}$$

$$= \frac{1}{\phi+g_A} \tag{90}$$

Therefore, the royalty revenue simplifies to:

$$\text{Royalty Revenue}_t = \eta\alpha\pi g_A \frac{1}{\phi+g_A} \tag{91}$$

$$= \eta\alpha\pi \frac{g_A}{\phi+g_A} \tag{92}$$

This means that royalty revenue is proportional to total profits (πA_t) scaled by three factors:

- η: The royalty fee

- α: The technology adoption ratio (A_t/T_t)
- $\frac{g_A}{\phi+g_A}$: The fraction of technologies that remain legitimate

The expression $\frac{g_A}{\phi+g_A}$ represents the fraction of technologies that generate royalties. This fraction approaches 1 when $\phi \to 0$ (perfect IPR protection) and decreases as ϕ increases (more imitation). It also increases with higher growth rates g_A, indicating that faster technology adoption counteracts imitation by introducing more new technologies that are initially legitimate.

A.3.3 Special Cases

For $\phi = 0$ (perfect IPR protection):

$$\text{Royalty Revenue}_t = \eta\alpha\pi\frac{g_A}{0+g_A} \tag{93}$$

$$= \eta\alpha\pi \tag{94}$$

For $\phi = 1$ (complete imitation after one period):

$$\text{Royalty Revenue}_t = \eta\alpha\pi\frac{g_A}{1+g_A} \tag{95}$$

B Model Solution Algorithm

We characterize the BGP of the economy and the associated transitional dynamics. The algorithm proceeds in two stages.

Balanced Growth Path

We start to solve the BGP equilibrium by making the initial guesses for the BGP blueprint allocation and the growth rate $\{\hat{Z}_n^*, g^*\}$:

(i) Guesses $\{\hat{Z}_n^*, g^*\}$, guess $\{\hat{\omega}_i^*, \eta_{in}^*, \frac{H_{in}^{A*}}{Y^*}\}$ to compute prices, trade shares, outputs, and value functions. We solve for the fixed point with three layers of iterations

  (a) iterate adoption rate $\frac{H_{in}^{A*}}{Y^*}$ and check against the first-order condition of $\hat{H}_{in}^{A*}$,

  (b) iterate wages $\hat{\omega}_i^*$ and check against balance-of-payments condition,

  (c) iterate licensing fee η_{in}^* and check against the first-order condition of Nash bargaining

(ii) Compute the implied $\frac{H_n^{R*}}{Y^*}$ and solve for a new $\{\hat{Z}_n^*, g^*\}$ applying Perron Frobenius Theorem. Iterate until it converges.

Transitional Dynamics

Assume the economy reaches the BGP at time T. To compute the transition from an arbitrary initial condition $\{Z_{n,0}, A_{in,0}, \mathcal{L}_{in,0}\}$ to the BGP, we employ time-path iteration:

(i) Set the BGP value functions as terminal conditions. Make an initial guess for the time paths of the jump variables $\{w^{n,t}, \eta_{in,t}, H_{in,t}^A/\bar{Y}_t, H_{n,t}^R/\bar{Y}_t\}_{t=0}^T$.

(ii) Given the state variables $\{Z_{n,0}, A_{in,0}, \mathcal{L}_{in,0}\}$, compute forward the sequences $\{Z_{n,t}, A_{in,t}, T_{n,t}\}_{t=1}^T$.

(iii) Update the time paths of the jump variables by imposing equilibrium conditions:

- Balance-of-payments conditions to iterate on wages $w_{n,t}$,
- Nash-bargaining conditions to iterate on licensing fees $\eta_{in,t}$,
- First-order conditions of innovation and adoption to iterate on $H_{in,t}^A/\bar{Y}_t$ and $H_{n,t}^R/\bar{Y}_t$.

(iv) Repeat until the entire system converges to a consistent transition path.

C BGP Analysis: An Increase of Geopolitical Distance

To illustrate how geopolitical distance affects equilibrium outcomes in the BGP, we analyze a three-country model where countries differ only in their IPR enforcement. Countries 1 and 3 maintain perfect IPR enforcement ($\xi_i = 1$), while country 2's enforcement varies between 0 (no enforcement) and 1 (perfect enforcement). The parametrization follows Table 11.

Parameter	Description	Value
β	Discount rate	0.98
β^A	Adoption curvature	0.50
β^R	Innovation curvature	0.50
σ	Elasticity of Substitution	5
ρ	Innovator's baseline bargaining power	0.25
$\bar{\epsilon}_{in}$	Baseline adoption efficiency	1 for $i = n$, 7.5 for $i \neq n$, 2.5 for $i \neq n$
d^G_{in}	Geographic distance	1 for $i = n$, 2.5 for $i \neq n$
d^P_{in}	Political distance	[1,1.693] for $in = 12, 21$, 1 otherwise
κ^G	Trade cost elasticity to geographic distance	1
κ^P	Trade cost elasticity to political distance	1
τ_{in},χ_{in}	Tariff and technology export control	0
L_i, Ω_i	Labor endowment and productivity	1
λ_i	Innovation efficiency	[0.1250, 0.0625, 0.1000]
ξ_{in}	IPR enforcement	0,1 for $i = 2$ and $i \neq n$, 1 otherwise
κ^ϕ	Elasticity of breach to political distance	1

Table 11: Simulation parametrization

The discount rate $\beta = 0.98$ corresponds to an annual interest rate of approximately 2%. We set the elasticity of substitution between varieties $\sigma = 5$, consistent with estimates in the international trade literature. The innovation and adoption curvature parameters (β^R and β^A) are both set to 0.50, reflecting diminishing returns to R&D investment.

For the technology transfer parameters, we set the innovator's baseline bargaining power $\rho = 0.45$. Adoption efficiency varies by country pair, with higher values for cross-country adoption to reflect the greater potential gains from international technology transfer.

The political distance between countries 1 and 2 varies so that the breach probability is between 0 (no political tension) and 0.35. All other country pairs maintain a political

distance of 1. The geographical distance is normalized to 1 for domestic transactions and 2.5 for international transactions. Innovation efficiency differs between countries, with country 1 ($\lambda_1 = 0.1250$) being the most innovative, followed by country 3 ($\lambda_3 = 0.10$) and country 2 ($\lambda_2 = 0.0625$).

Figure 11 illustrates the main channels. An increase in ϕ_{21} raises the probability of contractual breach, which decreases the adoption probability ϵ_{21} and the stock of adopted technologies A_{21}/T_2. Innovators respond by charging higher royalty rates η_{21}, yet this adjustment cannot compensate for the sharp contraction in licensed technologies. As a result, royalty payments $RP_{21}/\bar{Y}$ decline.

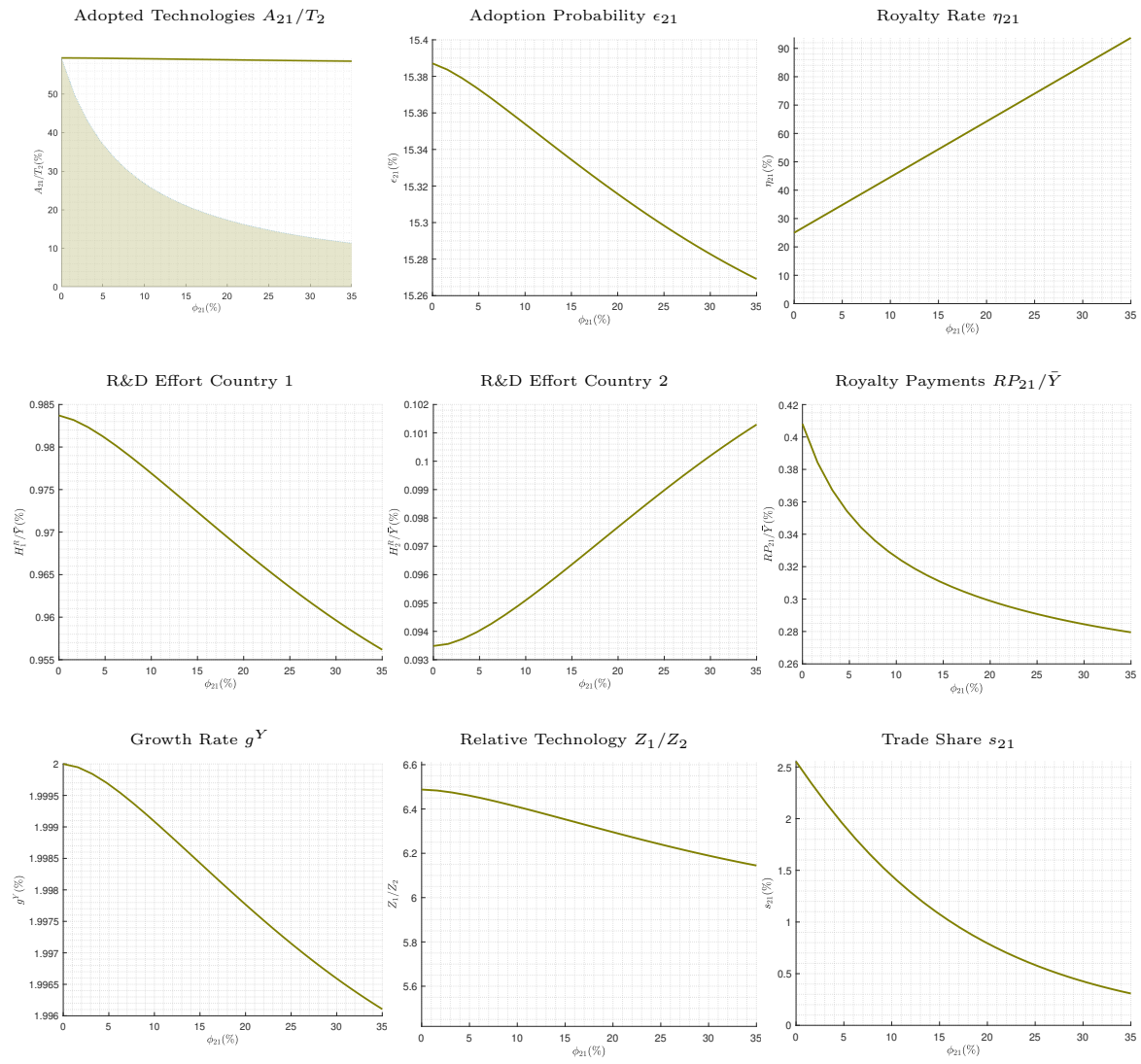
The fall in adoption weakens innovation incentives in the leading economy: country 1 reduces its R&D effort, $H_1^R/\bar{Y}$. By contrast, country 2 reallocates resources toward imitation-driven effort, slightly raising its $H_2^R/\bar{Y}$. This asymmetry reflects the model's central friction: weak IPR enforcement allows the follower to free-ride on the innovator under political tensions.

At the aggregate level, the decline in adoption and innovation lowers the growth rate g^Y. Moreover, relative technology levels shift in favor of the follower: the ratio Z_1/Z_2 falls, capturing the erosion of technological leadership in the innovating country. Finally, the bilateral trade share s_{21} declines, consistent with the standard gravity channel, but its magnitude is smaller than the decline in technology flows.

Technology transfers are *doubly exposed* to geopolitical frictions, through reduced market size and increased breach risk, making them more sensitive than merchandise trade to political distance. This explains both the efficiency costs of fragmentation and the strategic incentives for governments to intervene in order to preserve relative technological advantage.

To assess the relative importance of the two channels through which geopolitical distance operates, we compare the benchmark against two counterfactuals: (i) no market-size effect ($\kappa^P = 0$), so that geopolitical distance only increases breach risk; and (ii) only market-size effect ($\xi_2 = 1$), so that distance affects trade costs but contracts are perfectly enforced. The results show that the benchmark response is a combination of both mechanisms: breach risk dominates the contraction in adoption, while market-size effects amplify the decline in innovation and growth. When the market-size channel is shut down, surplus is reallocated toward the innovator, so that Z_1/Z_2 actually rises and

Figure 11: Effect of an increase in geopolitical distance between countries 1 and 2 on Balanced Growth Path allocations.



Notes: Simulation of the three-country model described in Table 11. Countries 1 and 3 maintain perfect IPR enforcement ($\xi = 1$), while country 2 has weak IPR enforcement ($\xi = 0$). The political distance between countries 1 and 2 increases so that the breach probability rises from 0 to 0.35.

a government concerned with relative technological leadership would have little reason to intervene. It is only when both channels are present that geopolitical distance reduces Z_1/Z_2, erodes innovation incentives, and creates the strategic motive for policy intervention observed in practice.

Figure 12 decomposes the benchmark results into two counterfactuals to isolate the channels through which geopolitical distance affects equilibrium outcomes. The solid line corresponds to the benchmark, the dotted blue line to the case with no market size effect ($\kappa^P = 0$), and the dotted black line to the case with only the market size effect ($\xi_2 = 1$).

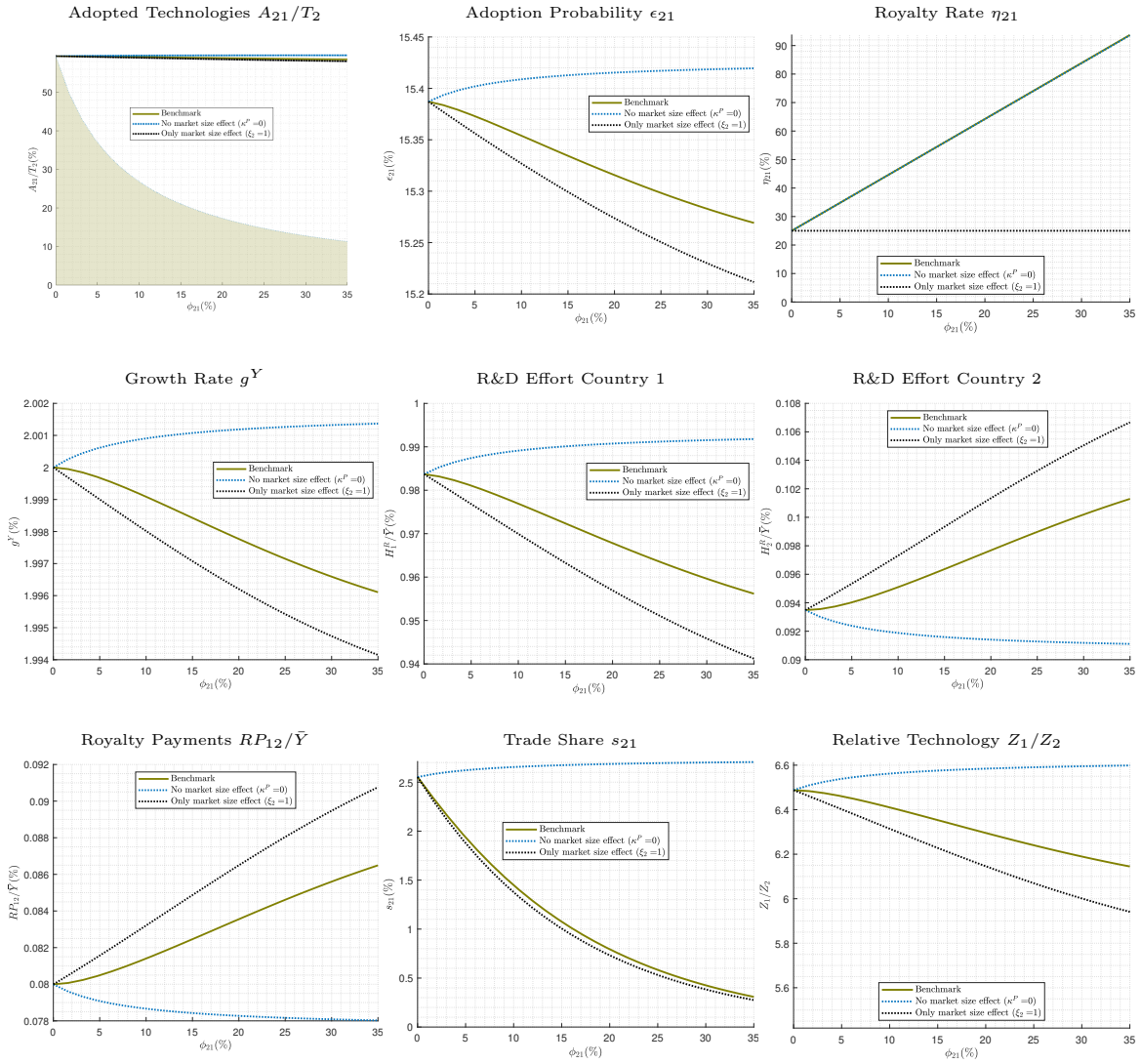
A somewhat counterintuitive result emerges when we shut down the market-size channel ($\kappa^P = 0$). In this case, greater geopolitical distance only raises breach risk, prompting higher royalty rates that shift surplus toward the innovator. Adoption does not decline, and country 1's R&D incentives actually strengthen. This is not a prediction of the full model, but rather an artefact of isolating the breach channel: absent market size effects, fragmentation simply redistributes rents in favor of the leader. As a consequence, Z_1/Z_2 rises, so the leader's relative technological position improves. In such an environment, a government motivated by national security concerns would see little reason to intervene.

It is only when market-size effects are also present that geopolitical distance lowers adoption, depresses royalty payments, and reduces innovation incentives. In this benchmark case, the decline in Z_1/Z_2 creates a clear strategic motive for intervention. The strong role of market size is consistent with the data: geopolitical distance reduces both trade flows and royalty payments, implying that fragmentation undermines innovation not only by raising breach risk but also by shrinking market opportunities. Hence both channels are essential for capturing the observed sensitivity of technology flows and for rationalizing why governments intervene on national security grounds.

In the absence of market size effects ($\kappa^P = 0$), adoption declines as breach risk rises, leading to a sharp fall in A_{21}/T_2 and ϵ_{21}. Royalty rates η_{21} increase strongly, but total royalty payments remain depressed. Innovation in country 1 falls moderately, while country 2's imitation-driven effort rises only slightly. By contrast, when only market size effects operate ($\xi_2 = 1$), adoption probabilities remain constant, but the decline in bilateral trade shares reduces the profitability of R&D, lowering growth and shifting relative technology levels.

Overall, the benchmark combines both channels: breach risk dominates the adoption

Figure 12: Benchmark vs. counterfactuals without market size effect ($\kappa^P = 0$) and with only market size effect ($\xi_2 = 1$).



Notes: The benchmark includes both channels: trade costs and breach risk rise with geopolitical distance. In the *no market size effect* case (blue dotted), only breach risk matters, so adoption falls strongly but trade shares remain flat. In the *only market size effect* case (black dotted), adoption is insulated by perfect IPR enforcement, but the contraction in trade shares reduces innovation incentives. The benchmark path lies between these polar cases, indicating that breach risk is the primary force behind the decline in technology transfer, while market size amplifies the effects on R&D and growth.

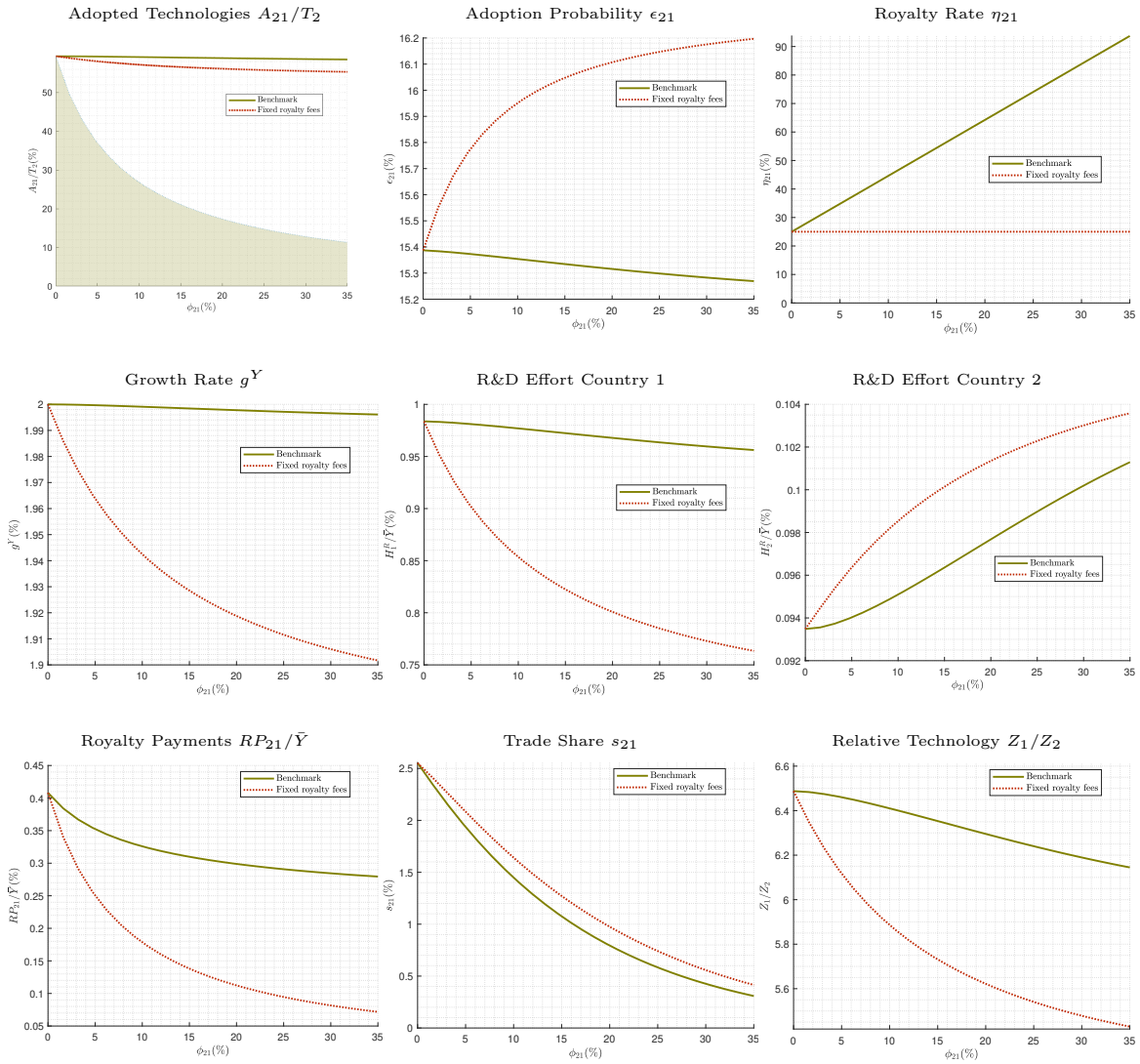
margin, while market size effects reinforce the contraction in innovation and the decline in long-run growth.

Finally, to assess the role of endogenous royalty renegotiation, we contrast the benchmark with a counterfactual in which the royalty fee is fixed at $\rho = 0.25$, so that it does not adjust to breach risk. The inability to raise royalty fees under political tension amplifies the adverse effects of geopolitical distance: adoption probabilities rise mechanically, but

innovators' revenues decline, sharply reducing R&D in country 1, accelerating catch-up by country 2, and generating a larger decline in aggregate growth. This illustrates that renegotiated royalty rates partly insulate innovators.

Figure 13 compares the benchmark equilibrium with a counterfactual in which the royalty fee is kept constant at $\rho = 0.25$. In this scenario, royalty rates do not adjust upward as breach risk rises, eliminating the contractual margin of protection for innovators. The comparison shows that endogenous royalty renegotiation mitigates, but does not eliminate, the adverse effects of geopolitical distance.

Figure 13: Benchmark vs. fixed royalty fees ($\rho = 0.25$).



Notes: With fixed royalty fees, adoption probabilities ϵ_{21} rise with distance because adopters face lower contractual costs, but innovators cannot adjust royalties to reflect higher breach risk. Consequently, royalty payments RP_{21} fall sharply, undermining R&D incentives in country 1 and leading to a faster relative catch-up of country 2 (Z_1/Z_2 declines steeply). The aggregate growth rate g^Y falls much more than in the benchmark, showing that renegotiation of royalty fees plays a stabilizing role in cushioning the growth impact of geopolitical fragmentation.

D Quantification

In this section, we extend the discussion of the model quantification. We report the parameters and model-moments that are not included in the main paper.

Adopter \ Innovator	USA	CAN	MEX	EU	CHN	JPN	KOR	ROW
USA	1.000	5.806	6.800	9.818	6.527	7.912	9.500	13.647
CAN	1.669	1.000	4.088	5.310	3.400	4.102	4.944	7.529
MEX	2.770	5.819	1.000	6.355	3.960	4.825	5.804	7.764
EU	3.315	5.930	5.388	1.000	3.423	4.286	4.627	6.245
CHN	5.343	9.681	8.043	7.979	1.000	4.407	4.594	9.583
JPN	4.775	8.554	6.983	7.640	3.297	1.000	4.416	8.308
KOR	3.839	6.925	5.638	5.969	2.286	2.971	1.000	6.818
ROW	2.697	5.035	3.606	3.740	2.412	3.294	3.781	1.000

Table 12: Geographic distance (d^G)

Adopter \ Innovator	USA	CAN	MEX	EU	CHN	JPN	KOR	ROW
USA	1.000	2.070	3.692	2.550	4.369	2.847	2.848	3.651
CAN	2.070	1.000	2.622	1.517	3.299	1.777	1.778	2.595
MEX	3.692	2.622	1.000	2.143	1.677	1.845	1.844	1.647
EU	2.550	1.517	2.143	1.000	2.820	1.313	1.326	2.179
CHN	4.369	3.299	1.677	2.820	1.000	2.522	2.521	1.848
JPN	2.847	1.777	1.845	1.313	2.522	1.000	1.123	1.954
KOR	2.848	1.778	1.844	1.326	2.521	1.123	1.000	1.962
ROW	3.651	2.595	1.647	2.179	1.848	1.954	1.962	1.000

Table 13: Geopolitical distance (d^P)

Adopter \ Innovator	USA	CAN	MEX	EU	CHN	JPN	KOR	ROW
USA	5.329	12.600	9.033	2.831	1.917	2.256	4.464	3.166
CAN	9.567	44.819	32.016	9.952	5.264	7.097	13.438	8.955
MEX	2.934	13.655	52.189	5.133	4.956	5.247	9.306	8.211
EU	2.042	9.205	10.588	7.970	2.173	3.698	6.561	3.583
CHN	1.064	3.741	9.054	1.652	4.494	2.465	5.457	2.647
JPN	2.680	10.992	16.734	6.637	4.725	13.131	19.976	5.093
KOR	3.823	14.804	25.063	8.050	8.409	17.276	29.803	7.260
ROW	1.306	4.897	10.514	2.226	1.881	1.971	3.621	5.549

Table 14: Adoption Efficiency ($\bar{\epsilon}_{in}$)

Adopter \ Innovator	USA	CAN	MEX	EU	CHN	JPN	KOR	ROW
USA	0.334	0.249	0.102	0.145	0.099	0.114	0.112	0.135
CAN	0.247	0.336	0.148	0.194	0.109	0.140	0.136	0.152
MEX	0.105	0.148	0.324	0.137	0.149	0.136	0.130	0.186
EU	0.139	0.186	0.129	0.334	0.122	0.176	0.174	0.156
CHN	0.106	0.117	0.150	0.132	0.329	0.185	0.204	0.169
JPN	0.112	0.135	0.130	0.172	0.175	0.325	0.320	0.136
KOR	0.117	0.141	0.129	0.186	0.200	0.329	0.333	0.142
ROW	0.131	0.150	0.186	0.166	0.154	0.145	0.140	0.334

Table 15: Model-implied adoption intensities (average $\epsilon_{in,t}$ along transition)

Adopter \ Innovator	USA	CAN	MEX	EU	CHN	JPN	KOR	ROW
USA	0.000	0.002	0.004	0.003	0.005	0.003	0.003	0.004
CAN	0.001	0.000	0.002	0.001	0.002	0.001	0.001	0.002
MEX	0.040	0.030	0.000	0.023	0.016	0.019	0.019	0.015
EU	0.014	0.006	0.011	0.000	0.015	0.004	0.004	0.012
CHN	0.069	0.056	0.024	0.049	0.000	0.044	0.044	0.029
JPN	0.008	0.004	0.005	0.002	0.007	0.000	0.001	0.005
KOR	0.010	0.006	0.006	0.003	0.009	0.001	0.000	0.007
ROW	0.034	0.025	0.013	0.020	0.016	0.017	0.018	0.000

Table 16: Breach Probability (ϕ_{in})

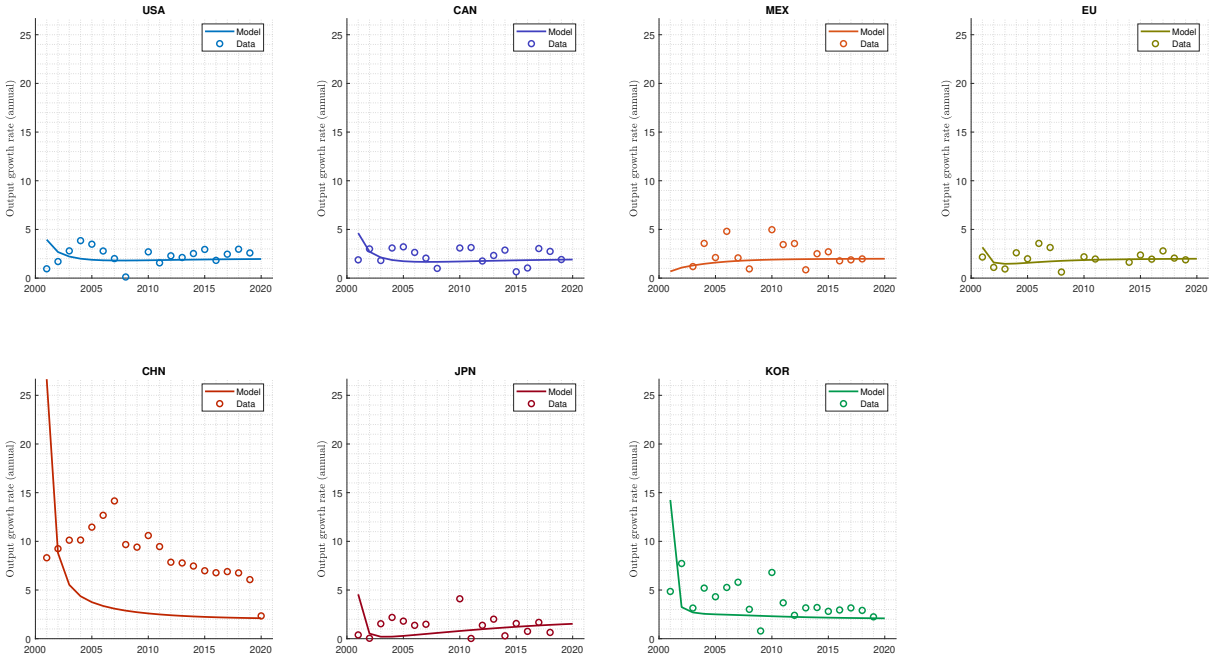


Figure 14: Transitional output growth rates

E Counterfactual analyses

In this section, we show the counterfactual paths where (i) η is fixed, (ii) the market size effect is fixed, (iii) the market size effect and η are both fixed.

Figure 15: Baseline versus Fixed η

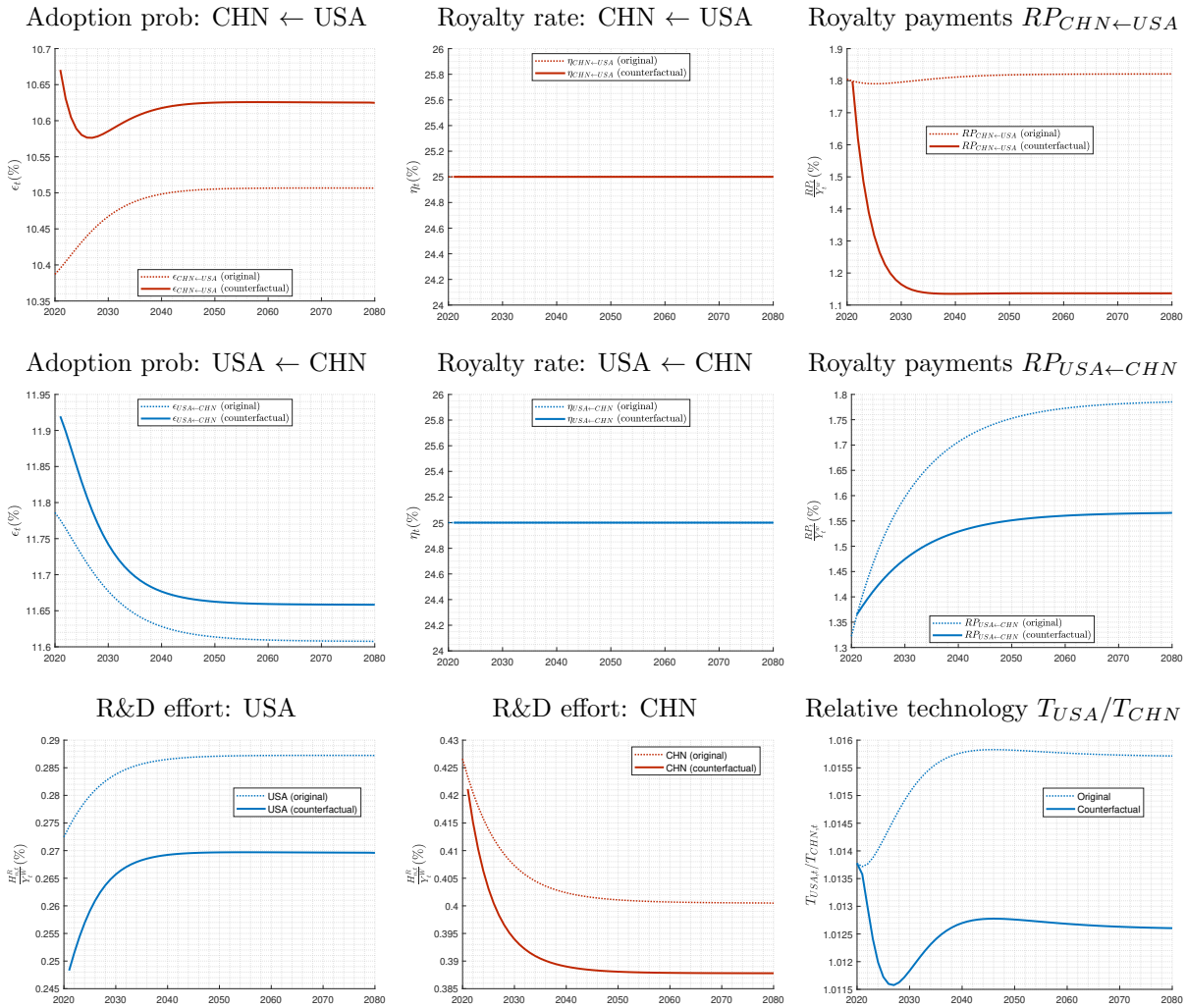
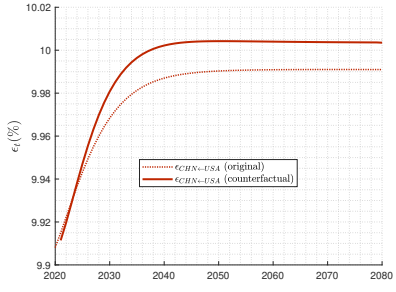
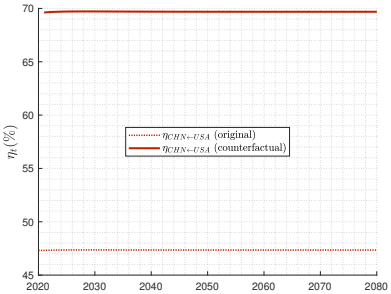


Figure 16: Baseline versus No Market Size Effect

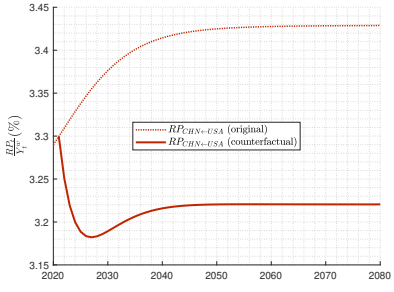
Adoption prob: CHN ← USA



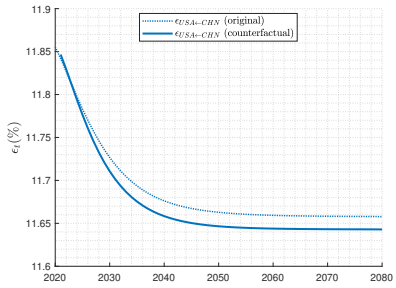
Royalty rate: CHN ← USA



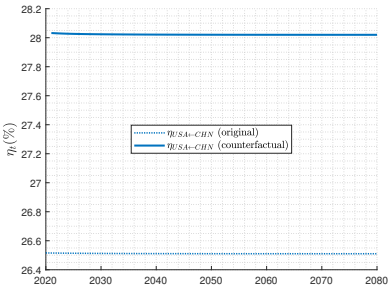
Royalty payments $RP_{CHN\leftarrow USA}$



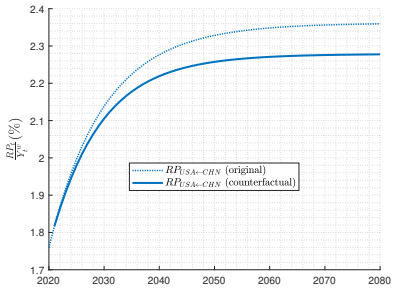
Adoption prob: USA ← CHN



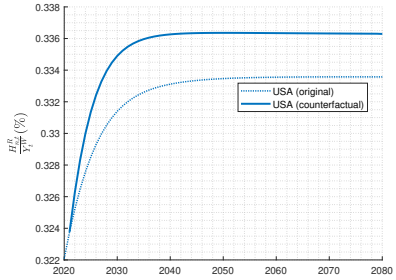
Royalty rate: USA ← CHN



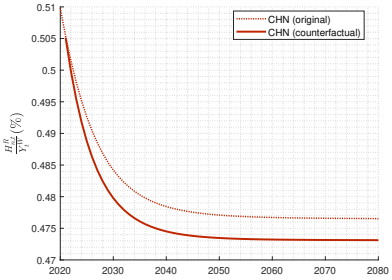
Royalty payments $RP_{USA\leftarrow CHN}$



R&D effort: USA



R&D effort: CHN



Relative technology T_{USA}/T_{CHN}

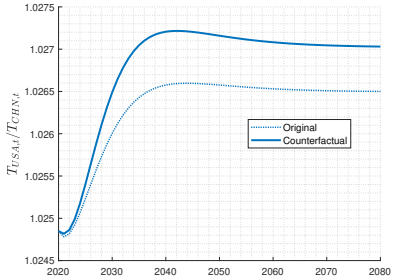


Figure 17: Baseline versus No Market Size Effect + Fixed η

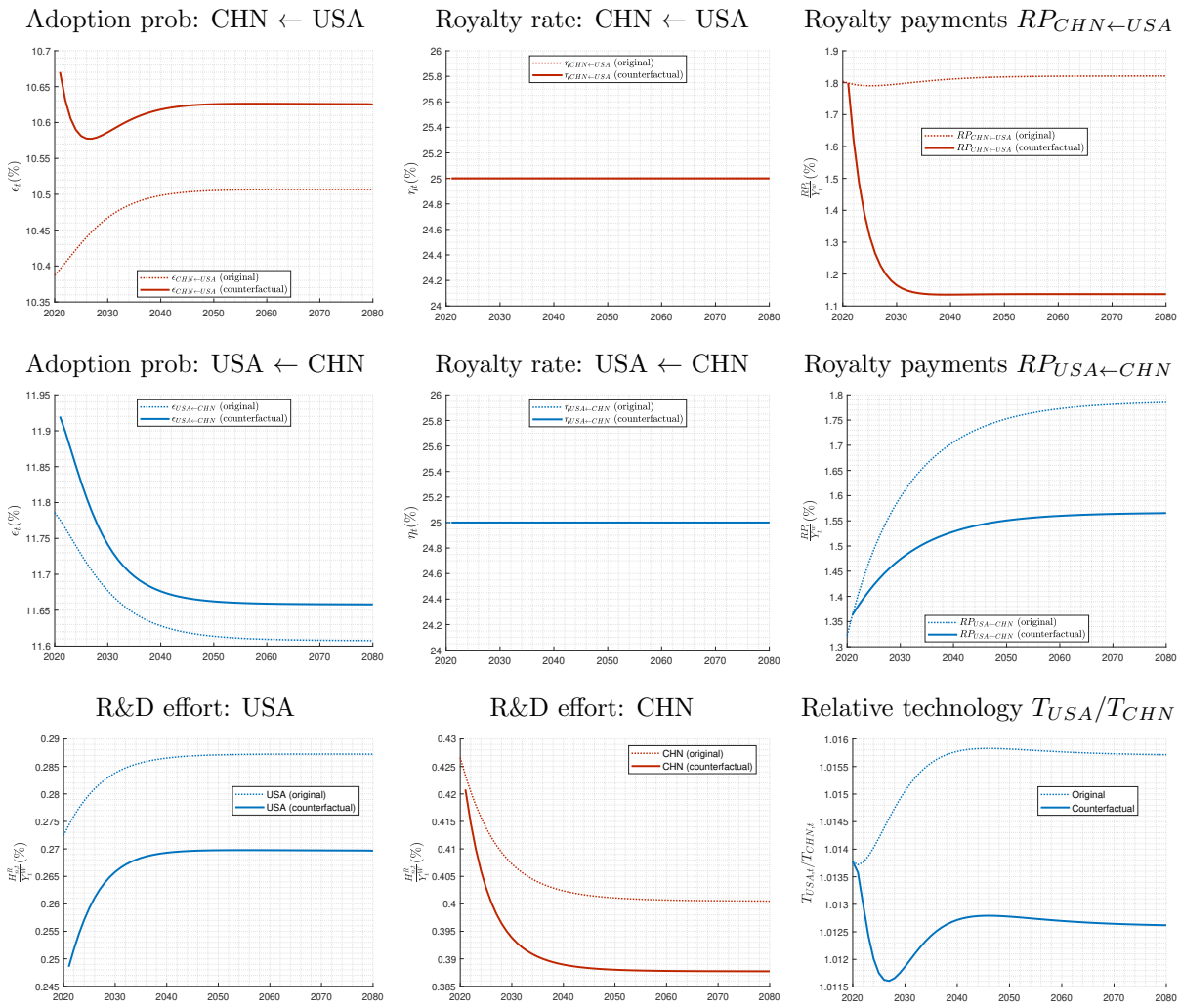
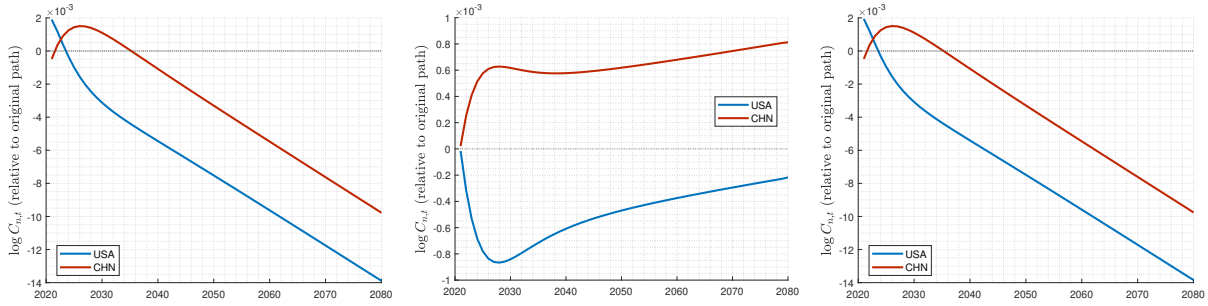


Figure 18: Counterfactual $\log C_t$ (relative to baseline)



F Technology Ban

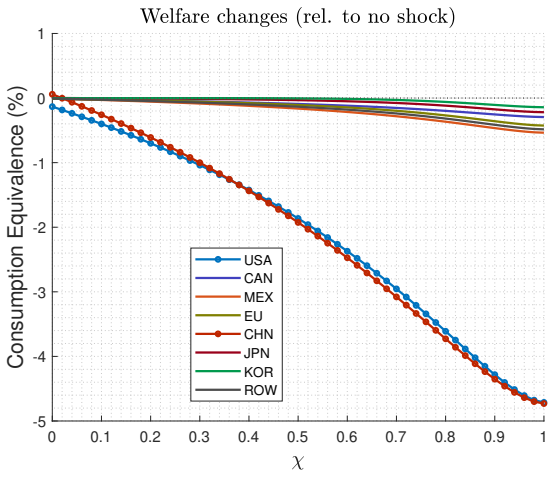


Figure 19: Consumption-equivalent welfare effects of export controls (χ) (China retaliates)

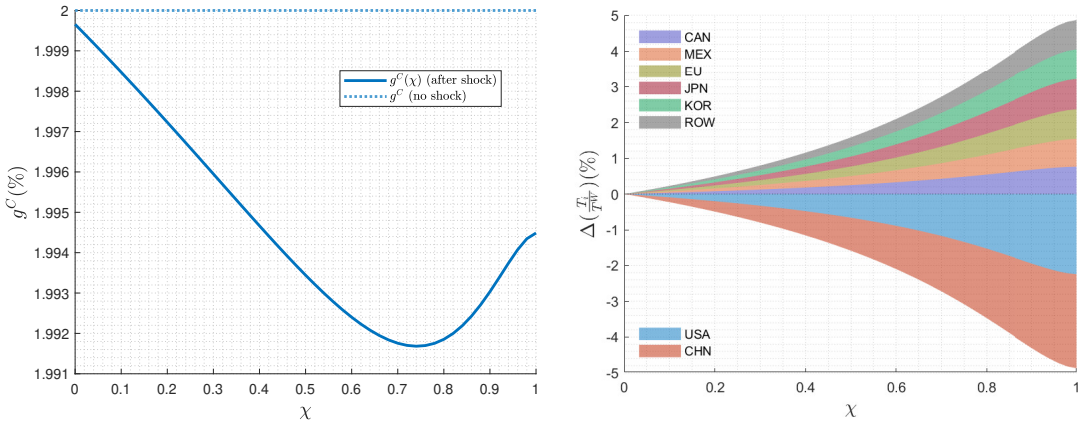


Figure 20: Changes in BGP growth rate and T distribution (China retaliates)