Intellectual Property, Tariffs, and International Trade

TECHNICAL APPENDIX

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[1]Beyond the usual disclaimers, we must note that any views in this paper are solely the responsibility of the authors and should not be interpreted as reflecting the views of the Federal Reserve Bank of Atlanta, or the Federal Reserve System.

A Data Appendix

Using the same data as in the main text, we consider an alternative specification, in which we control directly for R& D intensity of an industry, as well as its size as in the previous specification. We estimate the following equation:

$$ln(Roy_{it}) = \beta_0 + \beta_1 ln(Imports_{it}) + \beta_2 \frac{R\&D}{Sales} \beta_3 Size_{it} + T_t + \epsilon_{it}. \tag{A1}$$

As can be seen in the following table, even when we control for R& D intensity, the fact remains that imports from unaffiliated parties are a strong predictor of royalty receipts from unaffiliated parties.

Variable	(1) ln(Royalties)	(2) ln(Royalties)	(3) ln(Royalties)
ln(Unaff Imports)	0.568***	0.456***	0.387***
	(0.112)	(0.124)	(0.137)
$\frac{R\&D}{Sales}$	0.241***	0.205***	0.200***
	(0.061)	(0.061)	(0.059)
ln(Parent Emp)		0.630*	
		(0.335)	
ln(Parent Sales)			0.585**
			(0.286)
Observations	24	24	24
R-squared	0.738	0.776	0.776

Year FE included

*** p<0.01, ** p<0.05, * p<0.1

The message of the exercise in the main text does not change under this specification; multinational parent companies that import more from unaffiliated parties also transfer more technology, as measured by royalty receipts, from unaffiliated foreign parties.

B Model Equilibrium Conditions

The equations below constitute a system of 46 equations in 46 endogenous variables:

$$w, w^*, \tilde{d}, \tilde{d}^*, N_E, N_E^*, \tilde{\mathbf{z}}_X, \tilde{\mathbf{z}}_X^*, N_D, N_D^*, N_X, N_X^*, \tilde{v}, \tilde{v}^*, C_h, C^*, \mathbb{Q}, \tilde{\rho}_D, \tilde{\rho}_D^*, \tilde{\rho}_X, \tilde{\rho}_X^*, \tilde{d}_D, \tilde{d}_D^*, \tilde{d}_X,$$

$\tilde{d}^*_X, M, X, C_e, R, C, R^*, M^*, q, \lambda, \lambda^*, C^*_{\mathbf{a}}, C^*_{\mathbf{c}}, Y^*_{\mathbf{c}}, R^*_{\mathbf{c}}, M^*_c, y, y^*, \tau^*_t, \Pi_{h,t}, \Pi_{e,t}, \Pi^*_t$.

Of these endogenous variables, five are predetermined at time t: $N_D, N^*_D, M, M^*, M^*_c$.

Additionally, the model features five exogenous variables: ε^i_t with $i = \{\tau, \tau^*, q, Z, Z^*\}$.

B.1 Entrepreneurs

Technology Capital Accumulation:

$$M_t = X_t + (1-\delta_M)M_{t-1} \tag{B1}$$

$$M^*_t = X_t + (1-\delta_M)(1-h(q_t))M^*_{t-1} \tag{B2}$$

Budget Constraint

$$C_{e,t} + X_t = R_t M_{t-1} N_{E,t} + \mathbb{Q}_t q_t R^*_t M^*_{t-1} N^*_{E,t} + \Pi_{e,t} \tag{B3}$$

Optimality Conditions:

$$C^{-\gamma}_{e,t} = \lambda_t + \lambda^*_t \tag{B4}$$

$$\lambda_t = \beta \mathbb{E}_t \left\{ C^{-\gamma}_{e,t+1} \left(R_{t+1} N_{E,t+1} \right) + \lambda_{t+1} \left(1-\delta_M\right) \right\} \tag{B5}$$

$$\lambda^*_t = \beta \mathbb{E}_t \left\{ C^{-\gamma}_{e,t+1} \left(\mathbb{Q}_{t+1} q_{t+1} R^*_{t+1} N^*_{E,t+1} \right) + \lambda^*_{t+1} (1-\delta_M)(1-h(q_{t+1})) \right\} \tag{B6}$$

$$C^{-\gamma}_{e,t} \left(\mathbb{Q}_t M^*_{t-1} R^*_t N^*_{E,t} \right) = \lambda^*_t (1-\delta_K) M^*_{t-1} h'(q_t) \tag{B7}$$

where $h(q_t) = \varepsilon^q_t \left(\varepsilon^{\tau^*}_t\right)^{\phi^*} \left[q_t \exp(-\eta(1-q_t))\right]$ and $h'(q_t) = \varepsilon^q_t \left(\varepsilon^{\tau^*}_t\right)^{\phi^*} (1+\eta q_t) \exp(-\eta(1-q_t))$.

B.2 Firm Owners

Evolution Number of Firms:

$$N_{D,t} = (1-\delta)\left(N_{D,t-1} + N_{E,t-1}\right) \tag{B8}$$

$$N^*_{D,t} = (1-\delta)\left(N^*_{D,t-1} + N^*_{E,t-1}\right) \tag{B9}$$

Budget Constraints:

$$N_{E,t}\tilde{v}_t + C_{h,t} = w_t L + N_{D,t}\tilde{d}_t + \Pi_{h,t} \tag{B10}$$

$$\tilde{v}^*_t N^*_{E,t} + C^*_{\mathbf{a},t} = w^*_t L^* + w^*_{\mathbf{c},t} L^*_{\mathbf{c}} + R^*_{\mathbf{c},t} M^*_{\mathbf{c},t-1} + N^*_{D,t}\tilde{d}^*_t + \Pi^*_t \tag{B11}$$

Optimality Conditions:

$$\tilde{v}_t = \beta(1-\delta)\mathbb{E}_t\left[\left(\frac{C_{h,t+1}}{C_{h,t}}\right)^{-\gamma}\left(\tilde{d}_{t+1} + \tilde{v}_{t+1}\right)\right] \tag{B12}$$

$$\tilde{v}^*_t = \beta(1-\delta)\mathbb{E}_t\left[\left(\frac{C^*_{\mathbf{a},t+1}}{C^*_{\mathbf{a},t}}\right)^{-\gamma}\left(\tilde{d}^*_{t+1} + \tilde{v}^*_{t+1}\right)\right] \tag{B13}$$

B.3 Firms

Entry Cost:

$$R_t M_{t-1} = f_e \frac{w_t}{Z_t}, \text{ where } Z_t = \varepsilon^Z_t Z \tag{B14}$$

$$q_t R^*_t M^*_{t-1} = f^*_e \frac{w^*_t}{Z^*_t}, \text{ where } Z^*_t = \varepsilon^{Z^*}_t Z^* \tag{B15}$$

Free Entry Condition:

$$\tilde{v}_t = R_t M_{t-1} \tag{B16}$$

$$\tilde{v}_t^* = q_t R_t^* M_{t-1}^* \tag{B17}$$

Domestic Prices:

$$\tilde{\rho}_{D,t} = \frac{\theta}{(\theta-1)} \frac{w_t}{Z_t \mathbf{z}_D} \tag{B18}$$

$$\tilde{\rho}_{D,t}^* = \frac{\theta}{(\theta-1)} \frac{w_t^*}{Z_t^* \mathbf{z}_D^*} \tag{B19}$$

Export Prices:

$$\tilde{\rho}_{X,t} = \mathbb{Q}_t^{-1}(1+\tau_t)\tau \left[\frac{\theta}{(\theta-1)} \frac{w_t}{Z_t \tilde{\mathbf{z}}_{X,t}} \right] \tag{B20}$$

$$\tilde{\rho}_{X,t}^* = \mathbb{Q}_t(1+\tau_t^*)\tau^* \left[\frac{\theta}{(\theta-1)} \frac{w_t^*}{Z_t \tilde{\mathbf{z}}_{X,t}^*} \right] \tag{B21}$$

Dividends on Domestic Sales:

$$\tilde{d}_{D,t} = \frac{1}{\theta} \left[\tilde{\rho}_{D,t}\right]^{1-\theta} \left(C_{h,t} + C_{e,t}\right) \tag{B22}$$

$$\tilde{d}_{D,t}^* = \frac{1}{\theta} \left[\tilde{\rho}_{D,t}^*\right]^{1-\theta} C_t^* \tag{B23}$$

Profits (Dividends) on Exports:

$$\tilde{d}_{X,t} = \frac{\mathbb{Q}_t}{\theta}\left[\tilde{\rho}_{X,t}\right]^{1-\theta} C_t^* - f_X \frac{w_t}{Z_t} \tag{B24}$$

$$\tilde{d}_{X,t}^* = \frac{1}{\mathbb{Q}_t \theta}\left[\tilde{\rho}_{X,t}^*\right]^{1-\theta} \left(C_{h,t} + C_{e,t}\right) - f_X^* \frac{w_t^*}{Z_t^*} \tag{B25}$$

Total Profits:

$$\tilde{d}_t = \tilde{d}_{D,t} + \frac{N_{X,t}}{N_{D,t}} \tilde{d}_{X,t} \tag{B26}$$

$$\tilde{d}_t^* = \tilde{d}_{D,t}^* + \frac{N_{X,t}^*}{N_{D,t}^*} \tilde{d}_{X,t}^* \tag{B27}$$

Price Indexes for (*licensed)* Goods:

$$1 = N_{D,t}\left(\tilde{\rho}_{D,t}\right)^{1-\theta} + N_{X,t}^*\left(\tilde{\rho}_{X,t}^*\right)^{1-\theta} \tag{B28}$$

$$1 = N_{D,t}^*\left(\tilde{\rho}_{D,t}^*\right)^{1-\theta} + N_{X,t}\left(\tilde{\rho}_{X,t}\right)^{1-\theta} \tag{B29}$$

Export Cutoffs

$$\tilde{d}_{X,t} = f_X \frac{w_t}{Z_t} \frac{\theta}{k-(\theta-1)} \tag{B30}$$

$$\tilde{d}_{X,t}^* = f_X^* \frac{w_t^*}{Z_t^*} \frac{\theta}{k-(\theta-1)} \tag{B31}$$

Share of Exporting Firms

$$\frac{N_{X,t}}{N_{D,t}} = (\mathbf{z}_{\min})^k (\tilde{\mathbf{z}}_{X,t})^{-k} \left[\frac{k}{k-(\theta-1)}\right]^{k/(\theta-1)} \tag{B32}$$

$$\frac{N^*_{X,t}}{N^*_{D,t}} = (\mathbf{z}^*_{\min})^k (\tilde{\mathbf{z}}^*_{X,t})^{-k} \left[\frac{k}{k-(\theta-1)}\right]^{k/(\theta-1)} \tag{B33}$$

B.4 Additional Equations for Foreign

Appropriated Capital:

$$M^*_{\mathbf{c},t} = (1-\delta^*_K) M^*_{\mathbf{c},t-1} + h(q_t) M^*_{t-1} \tag{B34}$$

Consumption aggregators and relative prices/demand for licensed good and goods made using appropriated technology capital:

$$C_{\mathbf{a},t} = C^*_t + C^*_{\mathbf{c},t} \tag{B35}$$

$$C^*_{\mathbf{c},t} = Y^*_{\mathbf{c},t} \tag{B36}$$

Production in the appropriating sector:

$$Y^*_{\mathbf{c},t} = Z^*_t \tilde{\mathbf{z}}^*_D \Psi^* \left(M^*_{\mathbf{c},t-1}\right)^{\alpha} \tag{B37}$$

$$R^*_{\mathbf{c},t} M^*_{\mathbf{c},t-1} = \alpha Y^*_{\mathbf{c},t} \tag{B38}$$

$$w^*_{\mathbf{c},t} = (1-\alpha) Y^*_{\mathbf{c},t} \tag{B39}$$

B.5 Value added, Tariffs, and Trade variables

Balanced Trade:

$$\frac{1}{(1+\tau_t)}\mathbb{Q}_t N_{X,t}\left(\tilde{\rho}_{X,t}\right)^{1-\theta} C_t^* = \frac{1}{(1+\tau_t^*)} N_{X,t}^*\left(\tilde{\rho}_{X,t}^*\right)^{1-\theta}\left(C_{h,t}+C_{e,t}\right) \tag{B40}$$

Tariffs:

$$\tau_t^* = \varepsilon_t^{\tau^*}\left(\varepsilon_t^q\right)^{\phi}\tau^* \tag{B41a}$$

$$\tau_t = \varepsilon_t^{\tau}\tau \tag{B41b}$$

Value Added:

$$y_t = w_t L + N_{D,t}\tilde{d}_{D,t} + R_t M_{t-1} N_{E,t} + \mathbb{Q}_t q_t R_t^* M_{t-1}^* N_{E,t}^* \tag{B42}$$

$$y_t^* = w_t^* L^* + w_{\mathbf{c},t}^* L_{\mathbf{c}}^* + N_{D,t}^*\tilde{d}_t^* + R_{\mathbf{c},t}^* M_{\mathbf{c},t-1}^* \tag{B43}$$

Lump-sum Transfers from Tariffs

$$\Pi_{h,t} = \frac{\tau_t^*}{(1+\tau_t^*)} N_{X,t}^*\left(\tilde{\rho}_{X,t}^*\right)^{1-\theta} C_{h,t} \tag{B44}$$

$$\Pi_{e,t} = \frac{\tau_t^*}{(1+\tau_t^*)} N_{X,t}^*\left(\tilde{\rho}_{X,t}^*\right)^{1-\theta} C_{e,t} \tag{B45}$$

$$\Pi_t^* = \frac{\tau_t}{(1+\tau_t)} N_{X,t}\left(\tilde{\rho}_{X,t}\right)^{1-\theta} C_t^* \tag{B46}$$

C Alternative Model Specifications

C.1 Home's Subsidiaries in Foreign

The baseline model assumes that all licensed firms producing in the foreign economy are owned by foreign households. These foreign households also own the unlicensed firms in the standard specification. Therefore, when renting technology capital from home entrepreneurs, they internalize the fact that some of the appropriated capital might be used by their own unlicensed producers. In this alternative specification, we allow foreign subsidiaries of home's licensed firm to operate in the foreign economy. We, therefore, allow for home ownership of foreign operations, which mimics the idea of multinational production.

For tractability, we split the home households in three distinct types: home owners of firms that operate only domestically, home owners of foreign subsidiaries, and home entrepreneurs. As we explain in the main text, in principle, this setup could be modified to merge these three types of households into a single type of household that owns and operates multinational conglomerates which produce domestically, export, and offshore some of their production to their foreign subsidiaries. These home multinationals would invest in R&D, brands, and other intangible capital. In turn, this technology capital would be used both domestically and transferred subsidiaries overseas. We choose to keep these households separate in part for tractability, but also because modeling the households as separate entities allows us to consider the differential impact of changes in policy on different subsets of the population within Home and leaves open the possibility of analyzing the effects of policy changes on the income distribution.

Model changes In this alternative specification, we have added a new type of household in Home that owns the licensed subsidiaries in Foreign. Similar to the set-up for the entrepreneurial households, the owners of foreign licensed subsidiaries do not receive wages for running their own companies. These households reside in the home economy, have the same consumption preferences as other home households, and maximize utility in a similar fashion. The budget constraint for these owners of foreign sub-

sidiaries is:

$$\mathbb{Q}_t \tilde{v}_t^* N_{E,t}^* + C_{M,t} = \mathbb{Q}_t N_{D,t}^* \tilde{d}_t^* + \Pi_{M,t}^*, \tag{C1}$$

where $C_{M,t}$ is their consumption and $\Pi_{M,t}^*$ accounts for rebated tariffs.[2] These households hold a fully diversified mutual fund of subsidiaries located in the foreign economy. Their total income from ownership of the mutual fund is equal to aggregate dividends ($N_{D,t}^* \tilde{d}_t^*$), expressed in terms of the foreign currency. Purchases of entering firms in Foreign are denoted as $\tilde{v}_t^* N_{E,t}^*$, where $\tilde{v}_t^*$ is the stock value of the average firm in Foreign and $N_{E,t}^*$ denotes the newly entering firms in Foreign.

The maximization problem of these households delivers an Euler equation for share holdings that is similar to the one that emerges from the maximization problem of households that own the domestic firms. This Euler equation takes the form:

$$\tilde{v}_t^* = \beta(1-\delta)\mathbb{E}_t \left[\left(\frac{C_{M,t+1}}{C_{M,t}} \right)^{-\gamma} \frac{\mathbb{Q}_{t+1}}{\mathbb{Q}_t} (\tilde{d}_{t+1}^* + \tilde{v}_{t+1}^*) \right]. \tag{C2}$$

Recall that $\mathbb{Q}_t = \varepsilon_t P_t^* / P_t$ is the consumption-based real exchange rate and ε_t is is the nominal exchange rate. To better illustrate the role of international ownership in the model, we assume in here that *all* licensed producers in the foreign economy are owned by households in Home, whereas in the text, we took the other extreme by assuming all licensed producers in Foreign were owned by households therein. Therefore, the foreign households in this modified specification no longer derive income from ownership of licensed firms; instead, they receive income from labor provided to both licensed and unlicensed firms, ownership of unlicensed firms, and rebated tariffs. Their budget constraint is now defined as:

$$C_{\mathbf{a},t}^* = w_t^* L^* + w_{\mathbf{c},t}^* L_{\mathbf{c}}^* + R_{\mathbf{c},t}^* M_{\mathbf{c},t-1}^* + \Pi_t^*. \tag{C3}$$

The remaining optimality conditions are the same as those described in the main text, taking into account that the foreign households no longer own the foreign licensed firms.

[2] The functional form of the rebated tariffs is identical to the one defined for entrepreneurs and for the owners of home firms.

Notice that the model can be easily modified to analyze an intermediate case in which some of the foreign goods-producing firms are owned by the foreign households, as in the baseline model, and some are subsidiaries owned by residents of Home, as we have modeled here.

Model Dynamics Figure 2A depicts the transitional dynamics following a permanent increase in Home tariffs on imported goods from Foreign. The solid line depicts the baseline model (see Figure 1) and the dotted line reflects the alternative specification described in this section. Furthermore, blue lines represent Home variables and red lines represent Foreign variables.

The first two panels depict, respectively, the consumption dynamics for the owners of domestic firms and subsidiaries in this alternative specification. Notice that the consumption of the owners of the foreign subsidiaries declines substantially, whereas consumption for the owners of domestic firms increases. This is because an increase in tariffs on goods produced in Foreign and shipped to Home negatively affects foreign producers by reducing trade and causing depreciation of the foreign currency. In the third panel, we aggregate the consumption of both the owners of domestic producers and of foreign subsidiaries (dotted line) and compare it with the consumption of the firm owners in the baseline model in which home households only own home goods producing firms. By analyzing this comparison, we note two things. First, the consumption gains of the owners of home goods producers outweighs the losses experienced by the owners of foreign subsidiaries, as the aggregate consumption gain is positive. Second, comparing the change in firm owners' consumption in this alternative specification with that which emerges in the baseline, the decline in consumption for the owners of foreign subsidiaries mutes the consumption gains for domestic households relative to the baseline which only includes home ownership of domestic firms, though not substantially so.

Interestingly, the consumption of entrepreneurial households is also muted in this specification. The main reason for the smaller increase in consumption for these households is that firm entry in Foreign is relatively more subdued in this specification than in the baseline, which in turn means that there are lower royalty gains for entrepreneurs. This is because foreign households no longer own the licensed firms that

are producing in Foreign and therefore, they do not internalize the spillovers realized by unlicensed firms that result from licensed technology capital in Foreign. In the baseline, when foreign households pay licensing fees to the home entrepreneur, they not only increase firm entry, but also their stock of appropriated technology capital. In this set-up on the other hand, the licensed firms are owned by households in Home, which do not benefit from appropriation of the technology capital. Therefore, these households are unwilling to pay higher royalty fees for licensed technology, thereby reducing the total royalties received by the entrepreneurs. This has the additional effect of reducing the stock of appropriated technology capital, $M^*_{c,t}$, as less licensed technology is transferred to Foreign, reducing the stock that can be appropriated. Therefore, foreign consumption falls by slightly more in the long run following the increase in tariffs, as foreign unlicensed firms are not able to make up the short fall of foreign licensed goods.

For robustness, Figures 3A and 4A replicate the two key experiments we consider in the main text, under this alternative specification. While quantitatively different, the conclusions of these experiments remain unchanged: tariffs are an effective deterrent for weak protection of intellectual property, while weakening enforcement may be a strong deterrent for raising tariffs.

C.2 Financial Integration

The baseline model assumes financial autarky for all agents. Absent international borrowing and lending, the model implies balanced trade in all periods. In what follows we relax this assumption. As is standard in the open-economy macroenomics literature, we now allow households to trade one-period risk free bonds. A particularly interesting case is the one in which the home entrepreneurs can finance the royalty payments that the foreign entrants must incur in order to start operating.[3]

Model Changes When entrepreneurs are assumed to have access to international borrowing and lending, their budget constraint becomes:

[3]Model implications are similar if we instead assume that home firm owners have access to international capital markets.

$$C_{e,t} + X_t + q_{b,t}B_t + \Phi(B_t) = R_t M_{t-1} N_{E,t} + \mathbb{Q}_t R_t^*(q_t M_{t-1}^*) N_{E,t}^* + \Pi_{e,t} - B_{t-1}. \tag{C4}$$

Here, the level of debt carried into period t is denoted by B_{t-1}, where $q_{b,t} = 1/(1+r_t)$ is the price of newly issued debt (issued in period t) and r_t denotes the implicit interest rate on this debt. Bonds are assumed to be denominated in local currency. As in Schmitt-Grohe and Uribe (2002), we introduce an arbitrarily small cost of holding these bonds, $\Phi(.)$, to ensure model stationarity. This cost takes the following functional form: $\Phi(B_t) = \frac{\varepsilon}{2}(B_t)^2$, where ε is an arbitrarily small number. Home entrepreneurs trade these bonds with foreign households; therefore, the foreign household's budget constraint is modified to include bonds in a similar fashion.

The intratemporal optimality condition for the entrepreneurs delivers the conventional Euler equation:

$$q_{B,t} = \beta \mathbb{E}_t \left\{ \left(\frac{C_{e,t+1}}{C_{e,t}} \right)^{-\gamma} \right\} - \Phi'(B_t). \tag{C5}$$

Combined with the optimality condition governing the choice of bonds for foreign households, this Euler equation yields the modified risk-sharing condition:

$$\mathbb{E}_t \left\{ \left(\frac{C_{\mathbf{a},t+1}^*}{C_{\mathbf{a},t}^*} \right)^{-\gamma} \frac{\mathbb{Q}_t}{\mathbb{Q}_{t+1}} \right\} = \mathbb{E}_t \left\{ \left(\frac{C_{e,t+1}}{C_{e,t}} \right)^{-\gamma} \right\} - \frac{\Phi'(B_t)}{\beta}. \tag{C6}$$

The evolution of the home net foreign asset position of this economy is pinned down by trade balance as follows:

$$q_{B,t}B_t - B_{t-1} = \frac{1}{(1+\tau_t)} \mathbb{Q}_t N_{X,t} \left(\tilde{\rho}_{X,t}\right)^{1-\theta} C_t^* - \frac{1}{(1+\tau_t^*)} N_{X,t}^* \left(\tilde{\rho}_{X,t}^*\right)^{1-\theta} \left(C_{h,t} + C_{e,t}\right), \tag{C7}$$

where goods trade imbalances are financed via international borrowing or lending. We close the model with the market clearing condition for international risk-free bonds. By definition, home and foreign

holdings of this asset are in zero net supply worldwide: $B_t + B_t^* = 0$.

Model Dynamics Figure 5A illustrates the model dynamics following an increase in home tariffs, as in Figure 1 in the main text. The solid line depicts the baseline model with financial autarky, while the dotted line represents this alternative specification with international financial integration. Results are largely the same for both specifications. This result is unsurprising, as we consider only permanent shocks, which decreases the role of international risk-sharing. International bond trade plays a large role in settings with transitory and unexpected shocks; in environments with permanent shocks and perfect foresight, borrowing and lending are less important.

There are some differences that arise in this setting which are worth highlighting. In both specifications, an increase in home tariffs on foreign imports induces an increase in foreign firm entry. However, on impact, the increase in firm entry is even more robust under financial integration. In this alternative scenario foreign households can borrow internationally from the home entrepreneurs, allowing them to immediately increase investment in firm creation. Because the foreign household is borrowing on the international market in order to fund firm creation, the home entrepreneur benefits directly from this in the form of higher royalty payments. In practice, this international borrowing could be interpreted as a trade credit entrepreneurs provide to their costumers overseas. On impact, higher royalties boost aggregate income (output) in home. Furthermore, the increase in foreign firm creation, and thus rental of home technology capital, serves to boost the stock of appropriated technology capital in Foreign. In both scenarios, Foreign substitutes towards the unlicensed sector, building its stock of appropriated technology capital, but it is able to do so more quickly when it is able to finance its purchase of licensed technology capital for licensed firm creation. Therefore, this shift away from licensed firms and towards unlicensed ones happens faster when international borrowing is available to the foreign household.

C.3 Labor Mobility

The baseline model assumes that in the foreign economy, labor cannot move between the licensed and unlicensed sector. Given the model parameterization, this assumption implies that workers in the licensed sector have a relatively higher wages than those operating in the unlicensed (counterfeiting) sector. This assumption is empirically motivated; however, in this section we consider a specification in which the foreign labor market consists of a homogeneous labor input that can move freely across sectors.

Model Changes With total labor mobility, it must be the case that wages are the same across both sectors. We will denote this wage by w_t^* and we will assume that the foreign households have L^* units of labor, which they supply inelastically. Their budget constraint then becomes

$$\tilde{v}_t^* N_{E,t}^* + C_{\mathbf{a},t}^* = w_t^* L^* + R_{\mathbf{c},t}^* M_{\mathbf{c},t-1}^* + N_{D,t}^* \tilde{d}_t^* + \Pi_t^*. \tag{C8}$$

We have modified the baseline model here by allowing households to be employed in both the licensed, $L_{l,t}^*$, and unlicensed (counterfeiting) sectors, $L_{\mathbf{c},t}^*$. By definition $L^* = L_{l,t}^* + L_{\mathbf{c},t}^*$.

The production of the unlicensed sector is redefined as: $Y_{\mathbf{c},t}^* = Z_t^* \tilde{\mathbf{z}}_D^* \Psi^* \left(M_{\mathbf{c},t-1}^*\right)^{\alpha} \left(L_{\mathbf{c},t}^*\right)^{\alpha-1}$, where now the labor supply to this sector is elastic. Wages must therefore equal the marginal product of labor; thus the optimality condition for labor can be expressed as $w_t^* L_{\mathbf{c},t}^* = (1-\alpha) Y_{\mathbf{c},t}^*$.

Model Dynamics Figure 6A depicts the model response to an increase in home tariffs under the assumption of labor mobility. Model dynamics are similar to those in our baseline scenario, as seen in Figure 1 of the main text. Once tariffs are imposed, exports drop sharply, and production by the foreign licensed sector falls. As a result, on impact, labor is reallocated toward the unlicensed sector, which recall is assumed to produce non-tradable goods. At the same time, there is an increase in firm creation in Foreign in order to substitute away from consuming imported goods from Home following the trade disruption caused by the increase in tariffs. Over time, as a result of this sustained firm entry, the number

of of operating firms in the licensed sector expands. Therefore, there is a gradual reallocation of labor back toward the licensed sector. One can see the impact of this reallocation on wages; on impact, they fall dramatically, as many workers shift into the less productive unlicensed sector. As the licensed sector recovers, so do wages, though they never recover completely, as production has shifted away from large, productive exporters, towards smaller, less productive firms, as is standard in the Meltiz framework.

D Sensitivity Analysis

In this appendix, we conduct sensitivity analysis to a few key parameters in the model.

D.1 Curvature of Appropriation Function

In the baseline experiments, we set η equal to 10, following Holmes et al (2015). This choice for the value of this parameter, which governs the curvature of the appropriation function, is empirically motivated. Furthermore, setting η equal to 10 introduces curvature in the transfer function for technology capital that guarantees an interior equilibrium.

To highlight the role of this parameter in the model, we reconsider the case in which the foreign country retaliates to tariffs imposed by Home with greater appropriation of technology capital (see dashed line in Figure 3 in the main text). Here, we first allow for η to be equal to 9 as in the robustness check scenario discussed in the online appendix to Holmes et al (2015). This scenario corresponds to the solid line in Figure 7a. As can be seen, results under this alternative specification are largely the same as under the baseline scenario, discussed in the main text.

The high convexity in the baseline (i.e. $\eta = 10$) implies that entrepreneurs can get away with transferring small, or perhaps less important, ideas when the retaliation takes places, therefore protecting the most advanced and important ideas, or "crown jewels. Holmes et al (2015) mention that values lower than 9 for this elasticity will be inconsistent with their estimates based on patent counts. However, its informative for our analysis to consider a scenario with a much lower elasticity. The dotted line in Figure

7a displays the case where η is set to equal 5.

It is worth noticing that a much lower elasticity implies that it becomes remarkably harder for entrepreneurs to protect their "crown jewels." In response to the retaliatory increase in the level of appropriation enabled by the Foreign policy lever, home entrepreneurs are forced to dramatically reduced their transfer rate of technology capital in order to protect their most valuable ideas, thus fewer royalties are generated. Even though the transfer rate for technology falls, appropriators are able to appropriate relatively more technology, and therefore, the stock of counterfeited capital increases more quickly and by a greater amount. As appropriators build their stock of appropriated technology capital, they can produce relatively more, thereby displacing more licensed firms in both Home and Foreign. The displacement results in a relatively larger fall in US exports. When taking into consideration all these developments, we see that consumption in Foreign (Home) increases (falls) relatively with a lower elasticity in the transfer rate. Notice, however, that qualitatively, this scenario is very similar to the baseline case.

D.2 Strength of Retaliation

Here, we explore the role played by the parameters that govern the extent to which countries retaliate to actions taken by their counterpart, ϕ and ϕ^*.

Recall from the discussion of Figure 3 in the main text that Home consumption increases and Foreign consumption falls after tariffs are imposed on Foreign imports into Home. Furthermore, when foreign retaliates to tariffs with increased appropriation ($\phi^* > 0$) these results are reversed for both countries. In the baseline, ϕ^* is set to 5. In Figure 8a, we vary this, setting it equal to 2.5 and 10, represented by the solid and dotted lines, respectively. Qualitatively, the main results from the baseline experiment hold in these cases as well. However, the magnitude of Foreign's ability to retaliate depends crucially on the strength of their retaliatory response to Home's tariffs. In particular, we see that Foreign's ability to increase consumption at the expense of Home consumption is dampened considerably when $\phi^* = 2.5$. Likewise, when the retaliatory response is stronger ($\phi^* = 10$), consumption gains are much larger for

Foreign and consumption losses larger for Home.

The same logic applies to Figure 4 in the main text; in the absence of retaliation, Foreign can increase its consumption through increasing appropriation, but if Home retaliates to increased appropriation with higher tariffs, Foreign is again made worse off. In the baseline scenario, we set ϕ equal to 1. In Figure 9a, we instead allow ϕ to equal 0.5 (solid line) and 2 (dotted line). Again, the results of these alternative specifications are qualitatively the same as in the baseline case, but the strength of the retaliation impacts the magnitude of the effects. When ϕ is set low, it is difficult for Home to use retaliatory tariffs to revert the consumption losses it experiences when Foreign increases appropriation. However, if Home retaliates in a stronger way ($\phi = 2$), they are more able to increase their consumption through tariff retaliation to an increase in appropriation.

E Alternative Experiments

As part of China's accession to the WTO in 2001, the country signed on to the Trade-related Aspects of Intellectual Property Rights (TRIPS) agreement, as all countries must when they join the WTO. Therefore, when China was admitted to the WTO, they were required to both lower their import tariffs and to add protections for foreign intellectual property. By agreeing to adhere to the TRIPS agreement, countries agree to protect foreign intellectual property that enters their borders to the same extent that they would intellectual property belonging to domestic entities. Notice that this doesn't guarantee equal protection of IP across all member countries, but rather that all IP will be equally protected within a given country. To put this more concretely, this doesn't guarantee that US IP will be as well protected in China as it is in the United States, but rather that US IP will be protected as well as Chinese IP within Chinese borders. However, the TRIPS agreement also sets out a basic standard of IP protection which member countries implicitly agree to when entering into the WTO and its intent is to guarantee the protection of IPR across localities and to provide recourse when countries feel that their intellectual property is being systematically appropriated when deployed to a foreign country. Therefore, Chinese accession to the

WTO should have served to both decrease tariffs and to increase the enforcement of intellectual property rights.

Model simulation

In what follows, we simulate our baseline model to understand what would have happened if the actual drop in Chinese tariffs witnessed upon the accession to the WTO had also been accompanied by a complete halt to the appropriation of intellectual property as is intended under the TRIPS agreement.

Average Chinese tariffs on U.S. imports before the accession to the WTO were 18.7% (for these calculations, we consider the period 1992-2001). After that, tariffs fell drastically to an average of 5.9% (2002-2017). In order to better illuminate our point, in the simulations we assume that such a decrease in tariffs takes place immediately and on a permanent basis. Notice, however, that this closely reflects the actual sequence of events, as the bulk of the drop in tariffs took place right after the WTO accession, with tariffs falling from 16.15% in 2001 to 7.24% in 2002. Simultaneously, in Equation 3 in the main text, we set Θ equal to 0 to account for the simultaneous halt to IP appropriation in this counterfactual scenario. The Figure 10a illustrates the results of this simulation.

The model transitional dynamics highlight a steady decline in the stock of appropriated technology in Foreign, which accounts for both the steady depreciation of the pre-existing stock of appropriated technology capital and the lack of new technology appropriations after the policy change. Absent appropriation risk, entrepreneurs now transfer all their technology to their licensed firms in Foreign (i.e. q increases about 85% to reach a value of 1). A higher rate of technology transfer translates into higher royalty receipts from Foreign for home entrepreneurs. Furthermore, the decrease in tariffs is associated with a substantial real exchange rate appreciation (depreciation) in Home (Foreign) in the new equilibrium. The intuition for this change in the terms of trade is straightforward: a sizable drop in tariffs imposed on home goods leads to an increase in the foreign demand for home goods, thereby increasing their relative price with respect to the goods produced in Foreign.

The decrease in the appropriation of technology capital and the decrease in tariffs are jointly reflected in the evolution of foreign output. On impact, it increases robustly as the foreign economy becomes more efficient following trade liberalization. That is, labor is reallocated towards more productive exporting licensed firms, which benefit from the real exchange rate depreciation, as it shifts away from the less productive ones that face the increased competition from imports from Home. Over time, however, the better allocative efficiency among licensed firms triggered by trade liberalization is offset by the steady decline in output in the appropriating sector that results from less appropriation of technology capital, driving down aggregate output in Foreign. Therefore, consumption in Foreign will drop to mirror the permanent decrease in aggregate income; however, consumption smoothing contributes to consumption dropping immediately in Foreign, despite the initial increase in output. This drop in foreign consumption is further magnified by the decrease in transfers (i.e. rebated tariffs) and the real exchange depreciation that are the direct byproduct of lower import tariffs. Finally, in Home, the slight decrease in aggregate income is offset by the larger gains arising from the better terms of trade which leads to higher aggregate consumption in there. Overall this exercise illustrates that a WTO accession that requires both lower import tariffs and a halt to appropriation of technology capital is largely disadvantageous for the less developed foreign economy as consumption is remarkably lower than before.

References

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