Innovation Union: Costs and Benefits of Innovation Policy Coordination*

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Abstract

What is the scope for international cooperation in innovation policy in economies closely integrated via trade? We address this question by building a two-region innovation-driven growth model with endogenous technology diffusion via FDI. We use the model to analyse R&D subsidy cooperation in the EU, which has a common trade and monetary policy but where a coordinated innovation policy is still in its infancy. Stark differences in innovation capabilities between the West (old member states) and the East (new member states) shape optimal policies. Western countries have higher R&D efficiency and serve as primary sources of knowledge spillovers, through FDI-driven technology transfer. Cooperation is driven by two factors: correcting distortions from subsidy competition, the *strategic motive*, and leveraging *intertemporal knowledge spillovers* that sustain growth. A coordinated policy involves substantial subsidies for the West and taxes for the East, reflecting the West's superior R&D efficiency and role as a key source of knowledge spillovers. Both regions experience welfare gains, primarily by internalising cross-border spillovers. We find strong complementarity between innovation and FDI subsidies, showing that jointly supporting knowledge creation and diffusion yields greater benefits than implementing each policy in isolation.

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1 Introduction

The recent financial crisis amplified calls for stronger international economic policy coordination while simultaneously fueling movements toward greater policy independence. Some European nations advocate for deeper integration through an ”ever closer union” approach, emphasizing increased policy coordination. In contrast, the UK, through a historic referendum, opted to withdraw from the EU entirely. While there is broad consensus against reversing trade integration in the EU, opinions diverge sharply on the merits of unified or coordinated approaches in other policy domains, such as banking, fiscal, and innovation. Following the 2008 financial crisis, debates over completing Europe's Economic and Monetary Union gained urgency, focusing on the scope and necessity of a potential fiscal and banking union (Berger et al. (2018)).

In 2010, the EU launched the Innovation Union, a flagship initiative of the Europe 2020 strategy. This was an ambitious and wide plan; one aspect was the creation of a single market for innovation via the introduction of the Unitary Patent — a procedure aimed at radically cutting the bureaucratic cost of patenting in the EU. Another was strong financial support of innovative firms, grants/subsidies for innovative small-medium enterprises (SME instruments) and a specific innovation procurement budget (European Commission, 2015). Moreover, the Commission's recent proposal of a plan for a Common, Consolidated, Corporate Tax Base, which includes an R&D incentive, can be seen as a first step toward a unified tax treatment of R&D (d'Andria et al., 2017). The current Framework Programme, Horizon Europe, the main financial tool through which the European Union supports investment in research and development, is expanding its budget and scope (European Commission, 2023b). These and other initiatives from the Commission can be interpreted as initial steps toward a coordinated innovation policy. The recent report by former ECB president Mario Draghi strongly emphasised the centrality of innovation policy for European competitiveness in the global stage.

Motivated by these political and institutional developments, this paper provides a macroeconomic framework to evaluate the effects of innovation policy and assess the costs and benefits of policy coordination in an economic union.[1] One fundamental task in exploring these issues is to identify the key structural differences between countries and understand their role in shaping the aggregate effects of policy coordination and their distribution across regions. Another important task for the analysis of optimal policies is to identify the key market distortions that policy must correct.

There are large differences between EU members in innovation performance. These differences are especially pronounced when comparing the new member states (NMS), the eastern European countries that entered with the enlargement starting in 2004, with the old member states (OMS), all western European countries. Over 98% of all patents granted within the EU in 2008 came from the West, with a similar fraction for later years. Moreover, country-level patent shares reveal that all Western nations—except Greece and Portugal, whose shares of total EU patents are comparable to leading

[1] Although we focus on the policy debate in Europe, the ongoing technology policy war between the US and China provides additional motivation and scope for our study (e.g Krugman, 2023; Economist, 2023).

innovators in the East but remain very low (around 0.1–0.3%)—exceed the maximum patent shares of Eastern countries by a wide margin, underscoring the significantly greater innovativeness of the older member states.[2]. Business R&D, as a share of GDP, remains significantly higher in Western EU countries compared to their Eastern counterparts, averaging 1.31% and 0.5%, respectively, during 2008–2016. A similar disparity is evident in the employment share of scientists and engineers in manufacturing, with 7.2% in the West versus 4.2% in the East over the same period. Despite these gaps, there are promising signs of innovation dynamism in the NMS, suggesting the early stages of catching up. This innovation surge is accompanied by robust inward FDI flows. Drawing on firm-level data from the Business Environment and Enterprise Performance Survey (BEEPS), we provide fresh evidence of FDI spillovers, linking the innovation performance in NMS and other Central and Eastern European countries to the expanding presence of foreign firms and the accompanying rise in FDI.

These structural differences shape the development of our Schumpeterian growth model, which encompasses two major regions: the West and the East. In both regions, firms compete in quality for market leadership, with innovation investments driving improvements in product quality. Firms introducing higher-quality products displace incumbents, becoming market leaders. While higher-quality goods fuel aggregate growth, they also erode the rents of displaced incumbents, embodying the Schumpeterian concept of "creative destruction". The key asymmetry between the regions lies in the West's superior innovation capabilities, supported by a more efficient R&D technology. The regions are interconnected through trade and knowledge flows. Innovations generate knowledge spillovers that enhance the innovation efforts of other firms. However, these spillovers are locally biased, meaning firms learn more from other firms in the same economy than from firms located abroad. This bias further amplifies the *innovation gap* between the two regions. The innovation technology also exhibits a "congestion externality" at the region/sector level: as more workers are employed in innovation, the productivity of the marginal worker declines. Therefore, the optimal global allocation of innovation incentives may not involve concentrating innovation in the region with the highest R&D efficiency.

We model FDI as an "adaptive" R&D investment that firms undertake to transfer technology and establish production abroad. As such, FDI serves as a vehicle for cross-border knowledge spillovers, facilitating the flow of ideas across regions through multinational activity. That is — FDI endogenises international knowledge spillovers. When firms in the advanced Western region innovate, they can choose to offshore production to the East to capitalise on lower wages. However, this offshoring also transfers knowledge to the East, strengthening the innovation capabilities of Eastern firms and enabling them to challenge Western firms' leadership more effectively. Consequently, the decision to offshore is influenced by two opposing forces: the wage gap, which incentivises offshoring, in addition to creative destruction, which discourages it, as rising innovation in the East reduces the attractiveness of offshoring. Our primary policy instrument is a generic R&D subsidy incorporating direct support with tax incentives. Additionally, we evaluate the impact of subsidies targeted specifically at FDI.

There are two key reasons for international policy cooperation. Regions want to subsidise innova-

[2] See Figure A.1 in Appendix A

tion for strategic purposes: when a firm from one region innovates and takes the leadership, profits shift across borders, leading to higher income and welfare in the innovating region. Policy cooperation aims at reining-in the subsidy competition due to this *strategic motive*. Second, as typical of endogenous growth models, innovation is the engine of growth and *intertemporal knowledge spillovers* make the impact of innovation on growth more pervasive and long lasting. When a firm innovates, it produces knowledge on which future innovation builds. Firms do not take this into account and underinvest in innovation from a social point of view, giving scope for policy intervention.[3] In our open economy, knowledge spillovers are partially global, and the extent to which firms benefit from knowledge produced in other regions is significantly influenced by FDI. Policy cooperation thus has a stronger incentive to subsidise innovation to address the distortion created by knowledge spillover than in a closed economy. The global policymaker's approach to R&D subsidies or taxes depends on the relative strength of competing distortions. If strategic motives dominate, leading to inefficient competition, the policymaker may favour reducing R&D incentives through taxation. Conversely, if knowledge spillovers are the primary driver, cooperation tends to support stronger innovation incentives to fully internalise these spillover benefit.

The gains from policy cooperation then crucially depend on the relative strength of the strategic motive, which derives from firm profitability, as well as knowledge spillovers. In our framework, markups are constant but we explore different structures and intensity of spillovers. The baseline model is a "no-scale" Schumpeterian framework with semi-endogenous growth (e.g. Jones, 1995; Kortum, 1997; Segerstrom, 1998). In this class of models, knowledge spillovers weaken as the economy grows so that long-run growth does not depend on the size of the market and policy has only temporary effects on growth. This is the most "conservative" version of endogenous growth models to conduct policy analysis.[4]

We calibrate the model to aggregate and sectoral data to reproduce key facts of the EU economy, which we divide in two regions: the old member states, the West in the model, and the new member states, the East in the model. The semi-endogenous nature of our model yields a simple expression for steady-state growth, allowing us to directly identify the parameter that determines the intensity of knowledge spillovers — a key factor in our analysis — using long-run productivity growth statistics. We calibrate the technology gap between the two regions — the higher innovation efficiency of Western firms and the local bias in knowledge spillovers — to replicate key economic patterns. Specifically, the geographical distribution of market leadership between regions (relative market shares), labour cost differences, and disparities in R&D-to-GDP ratios. Given the lower labour costs in the East, Western firms are incentivised to offshore production. The extent of offshoring is calibrated to match

[3]The Schumpeterian model is particularly suited to study optimal innovation policy because, depending on the relative strength of the strategic motive and intertemporal spillovers, the market equilibrium can feature too much or too little innovation from the social point of view.

[4]The first generation endogenous growth models have the counterfactual prediction that larger countries have faster long-run growth. Weak knowledge spillovers solve this "scale effect" problem without preserving the endogeneity of the long-run growth typical of first generation models. A different approach is the one taken by the so-called fully-endogenous growth models, in which policies can affect long-run growth. See Jones (forthcoming) for a recent review of this literature.

the observed market share of Western multinationals (FDI) in the East

We compute the cooperative policy, that we call *harmonised* subsidies, obtained when a global policy maker chooses two potentially different subsidies for the two regions to maximise global welfare. This form of policy coordination can be interpreted as a simple formalisation of policies (e.g. research grants and loans), which the EU allocates to countries with the scope of stimulating innovation and growth in the union and promoting cross-country convergence. Policies in the Framework Program and the Cohesion Funds broadly target these goals and result in asymmetric subsidies across countries.[5] We compute the welfare gains from policy cooperation relative to the actual subsidies observed in the data, fully accounting for transitional dynamics and examining the effects across varying policy horizons. A detailed welfare decomposition further quantifies the contributions of key motives for cooperation, shedding light on their role in shaping the overall gains.

We find that subsidy harmonisation requires a substantial subsidy on Western firms' and a tax on Eastern firms' innovation. This cooperative planner's decision is driven by the higher R&D efficiency in the West and by the fact that its firms are key drivers of cross-border spillovers via their FDI activity. Since the West is the largest region, the increase in the Western subsidy implies that the average weighted subsidy in the union increases, thereby leading to more growth and substantial welfare gains, a 4.5% consumption increase compared to the status quo, with a significantly larger share of these gains accruing to the West. Offshoring activity surges as higher innovation in the West drives up labor demand and wages, while innovation taxes in the East dampen innovation and exert downward pressure on wages. This intensified offshoring significantly enhances the profitability and market shares of Western firms, allowing them to capitalize on the lower labor costs of overseas production. These dynamics lead to greater overall welfare gains for the West, driven by smaller losses through the strategic channel.

The main driver of these gains is the internalization of the distortionary effects of knowledge spillovers. In our economy, knowledge flows across regional borders, amplifying the growth effects of innovation subsidies. Western R&D not only boosts domestic innovation but also increases the potential for innovation abroad. These cross-border knowledge spillovers lead to a more significant market failure in an open economy, resulting in greater underinvestment in innovation, which the EU policymaker seeks to address. Therefore, the benefits of temporarily enhancing growth outweigh the advantages of correcting distortions caused by the strategic motives behind subsidies. This insight is further supported by showing that the gains from cooperation are decreasing in the cost of FDI.

Building on this, it is natural to consider the impact of FDI subsidies and how they interact with innovation subsidies. Cross-border knowledge spillovers from FDI are not accounted for by firms, when making their offshoring decisions. This gives potential for underinvestment in knowledge transfers

[5]The current framework program, Horizon Europe (2021-27), has a budget of 95.5 billion euros (European Commission, 2023b). The European Regional Development Fund (ERDF) aims to strengthen economic, social and territorial cohesion in the European Union by correcting imbalances between its regions. ERDF priorities are research and innovation, information and communication technologies, support for SME, and low-carbon economy. The 2021-27 cycle budget is 200.3 billion euros, a substantial part of which will be targeting research and innovation incentives (European Commission, 2023a).

via FDI, thereby motivating policy intervention. Our result suggests the presence of a notable *policy complementarity* where simultaneously subsidising knowledge creation (innovation) and knowledge diffusion (FDI) yields greater gains from cooperation than the sum of the individual policies applied separately.

Finally, we extend the model by introducing a third region, the Rest of the World (*ROW*), to capture the effects of non-EU trade and potential "trade diversion" resulting from regional innovation policy cooperation (West-East only). We model *RoW* as another advanced region, similar to the West, enabling us to broaden our analysis to include policy cooperation between regions with similar innovation potential. Our baseline results are confirmed in this extended setting, where the optimal West-East cooperative policy is to subsidise Western firms and tax Eastern. However, in this new scenario the gains are more equally shared between EU countries. This is due to trade diversion: cooperation boosts innovation in the West and technology diffusion to the East and, as a consequence, both W and E firms expand their market shares at the expense of *RoW*, which is policy passive in this exercise. When considering a global policy maker coordinating subsidies across all three regions, the optimal policy remains to subsidise the West, tax the East, and also tax the *ROW*. Notably, cooperation with the more advanced *ROW* leads to significantly larger gains for Western Europe compared to cooperation with the less advanced Eastern European region.

Literature review. The main related literature is the recent body of work in "quantitative growth theory" analysing the effects of innovation policy both in closed economy (e.g Acemoglu and Akcigit, 2012; Acemoglu et al., 2018; Akcigit et al., 2016) and in open economy (e.g Impullitti, 2010; Akcigit et al., 2018b). Surprisingly, there is very little macroeconomic work on international cooperation in innovation policy. Grossman and Lai (2004) and Kondo (2013) propose theoretical analyses of the gain from intellectual property rights policy (IPR) cooperation in endogenous growth models. Hemous et al. (2023) incorporate the key insights from Grossman and Lai (2004) into a large-scale quantitative model to assess the benefit from cooperation in IPR. Santancreu (forthcoming) presents a quantitative growth model of bilateral trade agreements with IPR provisions to analyze the dynamic policy trade-offs. To the best of our knowledge, ours is the first and only paper studying the gains from cooperation in R&D subsidies. We also contribute to the literature by examining how knowledge spillovers influence the benefits of policy cooperation. Our analysis highlights that endogenising international knowledge spillovers through FDI positions economic growth as a central driver of welfare gains. Specifically, we demonstrate that knowledge spillovers — and the associated underinvestment in innovation — are pivotal to realising the benefits of global policy cooperation.

Several papers have introduced FDI in endogenous growth models (e.g. Branstetter and Saggi, 2011; He and Maskus, 2012; Acemoglu et al., 2015; Segerstrom and Jakobsson, 2017). Dinopoulos and Segerstrom (2010) introduce FDI in a North-South Schumpeterian growth model to study the effects of an increase in IPR protection on innovation and the wage gap between countries. In their model, Northern firms innovate while Southern firms can only imitate. Our model is more general in that firms in the lagging region are also allowed to innovate. We contribute to this literature studying the role of FDI in shaping the gains from innovation policy cooperation.

The strategic motive for subsidies has been widely studied in the strategic industrial policy literature. Contributions focusing on R&D subsidies are the pioneering Spencer and Brander (1983), and the following work by Leahy and Neary (1997), Leahy and Neary (2009) and Haaland and Kind (2008) among others. Papers analysing the strategic role of trade policy include Eaton and Grossman (1986), Maggi (1996), and more recent contributions by Felbermayr et al. (2013) and Campolmi et al. (2018) among others. In a sequence of recent papers Ossa (2011), (2014), (2015) revisits the key questions in the literature with a modern quantitative approach. Our paper is also related to the recent literature on "deep" trade agreements, whereas cooperation goes beyond the reduction or elimination of traditional barriers to trade, such as tariffs and quotas and include provisions for a broader range of policy areas such as investment, intellectual property, regulatory alignment, labour and environmental standards (e.g. Grossman et al., 2021; Maggi and Ossa, 2023). Our contribution to these lines of work is to cast the analysis in a dynamic framework and show that internalising intertemporal knowledge spillovers, that is internalising the growth effect of policies, is crucial and quantitively relevant for the gains from cooperation.[6] We also contribute analysing the role of FDI as a vechicle of knowledge diffusion.

2 FDI and innovation in Eastern Europe

FDI in the NMS of Eastern Europe doubled in the post- EU accession period. The bulk of the FDI received by these countries, more than 80%, comes from old EU members[7]. There is extensive literature documenting the positive effects of FDI spillovers on the productivity of local firms (e.g. Javorcik, 2004; Keller, 2004; Lu et al., 2017; Setzler and Tintelnot, 2021). The typical spillover channels highlighted in existing works include technology transfers, supply chain interactions, and labor mobility. Less attention has been devoted on the impact of FDI on the innovation activity of firms in the receiving country.

Here we present a brief empirical analysis of the relationship between FDI and domestic firms' innovation at the regional level using the Business Environment and Enterprise Performance Survey (BEEPS) data for Eastern and Central European countries for the years 2011–2014—a period during which the exact location of firms can be observed at the regional level. This firm-level survey, based on face-to-face interviews with managers, includes 15,694 firms located in 30 Eastern and Central European countries, as well as some Commonwealth of Independent States, including Russia and Turkey. For those years, the data provide information at the firm-level, including foreign ownership, two-digit sector classification, and exact regional location—usually defined at the NUTS-2 level.[8]

[6] This results echoes the recent finding in the trade and growth literature showing that the *dynamic gains* from trade magnify the gains obtainable in static trade models (e.g. Sampson, 2016; Impullitti and Licandro, 2018), Perla et al. (2015).

[7] See figure A.3 in the Appendix.

[8] Exceptions include Estonia, Latvia, Lithuania, and Russia, where regions are more disaggregated at the NUTS-3 level,

A key feature of the BEEPS survey is that it includes several questions on product and process innovation. The data provide self-reported information from top managers on various types of innovation activity, including developing new products or services, adopting new production or supply methods, implementing new organizational or management practices and structures, and introducing new marketing methods.

Using a firm-level linear probability model, we focus on domestic firms and define our dependent variable as a dummy variable that takes the value of one if the firm reports product or process innovations and zero otherwise. We construct our main explanatory variable in two ways: first, as a *dummy* variable indicating the presence or absence of a foreign firm within the same region and 2-digit sector as the firm, and second, as the *share* of foreign firms among all firms within the same sector and location.[9] Table 1 reports our main results, with all estimations including year, sector, and region fixed effects, thereby controlling for any sectoral or regional size or specific effects. Using two-way clustering, we report robust standard errors clustered at both the regional and sector levels. Regressions (2) and (4) also include additional firm-level controls: the log of firms' sales and a set of dummy variables for state-owned enterprises, as well as for exporting and importing status.

Table 1: Domestic firms reporting innovation and foreign presence

Dependent variable: Firm-level dummy variable for domestic firms reporting innovation				
Explanatory variable:	Dummy	Dummy	Share	Share
	(1)	(2)	(3)	(4)
Foreign presence	0.038**	0.039***	0.237***	0.205***
	(0.014)	(0.013)	(0.068)	(0.065)
Control variables	No	Yes	No	Yes
Observations	13,843	10,593	13,843	10,593
R-squared	0.164	0.208	0.164	0.208

Notes. All regressions include region, sector and year fixed effects. Regressions (2) and (4) include the following firm-level control variables: firms' log of sales, and a set of dummy variables for state-owned enterprises, exporting firms, importing firms. Robust standard error clustered both at the region and at the sector level into brackets. *, **, *** significantly different from 0 at 10%, 5% and 1% level, respectively.

The coefficient associated with "foreign presence" is significant at least at the 5% level in all estimations. In Column (1), a foreign presence in a region-sector is associated with an increase of 3.8 percentage points in the predicted probability for a domestic firm to report innovation. In column (3), increasing the share of foreign affiliates among all firms from the 25th percentile to the 75th percentile (respectively 0 and 0.04) is associated with a 1 percentage point increase in the predicted probability of a domestic firm innovating. In the appendix, we split the sample in various ways, and as reported in Table A.1, excluding all region-sector pairs with fewer than or more than 30 active firms yields

and Hungary, Poland, Turkey, and Ukraine, where regions are more aggregated at the NUTS-1 level.

[9] We define a foreign affiliate as a firm with at least 50 percent of its capital owned by a foreign entrepreneur or company.

qualitatively similar results, with effects of comparable magnitude. Beyond controlling for sector- and region-specific effects, we also include the number of observations and the logarithm of the number of observations per country-region as control variables. We find more pronounced effects for private firms compared to state-owned enterprises. The effects also persist for both small and large firms (below or above the median size) and appear independent of the firm's export or import status.

Our findings do not establish causation; however, they underscore the geographic clustering of domestic innovative firms in sectors with active foreign affiliates. These results align with and complement the work of Gorodnichenko et al. (2010) and Gorodnichenko et al. (2020), who use similar data for the same set of countries but during a different time period.[10] While they use firm-level sales to multinational affiliates to identify vertical linkages between domestic firms and foreign affiliates, we adopt a broader definition that captures the presence of foreign affiliates within the same region-sector.

3 The Model

We analyze an economy comprising two regions: the West (W), representing the old EU member states (OMS) in our quantitative analysis, and the East (E), representing the new EU member states (NMS). Labor in each region is allocated across three activities: manufacturing goods, innovative R&D, which enhances product quality, and adaptive R&D, which facilitates the transfer of production abroad. Firms in both regions compete on quality to achieve market leadership, with product quality advancing through investments in innovation. The two regions are separated by a *technology gap*, reflecting the higher innovation efficiency of Western firms compared to their Eastern counterparts.[11]

Our model incorporates the stylized facts on FDI and innovation presented in Section 2. Specifically, we assume that Western firms, upon achieving a successful innovation, can choose to offshore production to the East if it is profitable. The technology gap, stemming from differences in innovation efficiency, creates disparities in market leadership and labor costs, incentivizing Western firms to offshore. Offshoring requires firms to allocate resources to adapt and transfer their technology abroad, an activity we term *adaptive R&D* or *FDI* to distinguish it from the research aimed at improving product quality. The newly established offshore operations are referred to as Western multinationals.

A defining feature of FDI is its role as a conduit for cross-border knowledge spillovers, enabling ideas to flow across regions. When Western firms relocate production to the East, the knowledge capital stock in the East increases, enhancing the R&D productivity of innovating firms there. This creates a positive link between FDI and innovation in the East, consistent with the empirical evidence in Table 1.

Upon a successful quality innovation in either region, the innovating firm secures global market

[10] The information on the exact regional location of firms is only available for the years 2011–2014. Unfortunately, the data on firm-level sales of multinational firms as used by Gorodnichenko et al. (2010) and Gorodnichenko et al. (2020) is not available for those years.

[11] Nelson (1993) documents how well-designed institutions and infrastructure can create systemic innovation efficiencies that benefit all firms within a country.

leadership in its sector, protected by a patent until displaced by a domestic or foreign competitor. Trade between the two regions incurs costs, and sectoral leadership evolves dynamically through a product cycle involving FDI and leapfrogging across regions. Specifically, this cycle includes the transfer of production from the West to the East, Eastern firms leapfrogging over multinationals, and eventual product quality advancements by the West to reclaim sectoral leadership.

3.1 Households

Our two-region economy, East and West, is populated by households which have the same intertemporal additively separable preferences over an infinite set of varieties/sectors indexed by $\omega \in [0,1]$. Each household is endowed with a unit of labour time whose supply generates no disutility. Households choose their optimal consumption bundle for each date by solving the following optimization problem:

$$\max U^K = \int_0^\infty L_0 e^{-(\rho-n)t} \log u^K(t) dt \tag{1}$$

subject to

$$u^K(t) \equiv \left(\int_0^1 \left[\sum_{j=0}^{j^{\max}(\omega,t)} \lambda^{j(\omega,t)} d^K(j,\omega,t) \right]^{\frac{\sigma-1}{\sigma}} d\omega \right)^{\frac{\sigma}{\sigma-1}}$$

$$c^K(t) \equiv \int_0^1 \left[\sum_{j=0}^{j^{\max}(\omega,t)} p^K(j,\omega,t) d^K(j,\omega,t) \right] d\omega$$

$$W^K(0) - \int_0^\infty L_0^K e^{-\int_0^t \left(r^K(s)-n\right)ds} T^K(t)dt = \int_0^\infty L_0^K e^{-\int_0^t \left(r^K(s)-n\right)ds} c^K(t)dt,$$

where $K = W,E$ indicates the region, u_t^K is the instantaneous utility, c_t^K is per-capita nominal expenditure across variety, and the final equation is the lifetime budget constraint. L_0^K is the initial population and n is its constant growth rate, ρ is the common rate of time preference — with $\rho > n$ —- and $r^K(t)$ is the market interest rate on a risk-free bond. $d^K(j,\omega,t)$ is the per-capita flow of goods in sector ω, each good of quality level $j \in \{0,1,2,...\}$, purchased by a household at time $t \geq 0$. $p^K(j,\omega,t)$ is the price of a good of quality level j in sector ω at time t, and $W^K(0)$ is the present value of wealth from labour and financial returns. A new vintage of a good ω yields a quality equal to λ times the quality of the previous vintage, with $\lambda > 1$. $j^{\max}(\omega,t)$ denotes the maximum quality in which the good in sector ω is available at time t. As is common in quality ladder models we will assume price competition at all dates, which implies that in equilibrium only the top quality product is produced and consumed in positive amounts in each sector ω. Finally, $T^K(t)$ is the per-capita lump-sum tax used to finance government subsidies to the R&D activities in the economy. We assume governments run balanced budgets every period.

The instantaneous utility function is a quality-augmented CES consumption index, with $\sigma > 1$.

Households maximise static utility by spreading their expenditures $c(t)$ across the product lines and purchasing in each line only the product with the lowest price per unit of quality, that is the product of quality level $j = j^{\max}(\omega,t)$. Hence, the household's demand of each product is:

$$d^K(\omega,t) = q(\omega,t)p^K(\omega,t)^{-\sigma}\frac{c^K(t)}{P^K(t)^{1-\sigma}}, \tag{2}$$

where $q(\omega,t) = \lambda^{j(\omega,t)(\sigma-1)}$ is a measure of the good's quality and $P^K(t) = \left[\int_0^1 q(\omega,t)p^K(\omega,t)^{1-\sigma}d\omega\right]^{\frac{1}{1-\sigma}}$ is the quality-price index. As we will show next, goods prices are different in the two regions due to the presence of trade costs. The intertemporal consumption choice leads to

$$\frac{\dot{c}^K(t)}{c^K(t)} = r^K(t) - \rho, \tag{3}$$

the standard Euler equation.

3.2 Product market

In each region, firms can hire workers to produce any consumption good $\omega \in [0,1]$ using a linear technology with unit labour requirement a^κ, where $\kappa = W,E,M$ is the producer indicator for the Western (W) and the Eastern (E) innovators, and the multinational firms (M), respectively. The wage rate in $K = W,E$ is denoted by w^K. Patent rights are protected globally by a perfectly enforceable EU-wide patent law. As is usual in Schumpeterian models (e.g. Grossman and Helpman (1991b) and Aghion and Howitt (1992)), firms conduct R&D activity to improve their good's quality and obtain market leadership. The innovation size is fixed at $\lambda > 1$, so that when an innovation arrives, λ measures the quality gap between the leader and the follower. The patent system grants the quality leader a temporary monopoly which is destroyed when the firm is leapfrogged by the next innovator.[12]

We assume that there is an iceberg trade cost $\tau^K \geq 1$, such that for one unit of any good to arrive from a producer in location K to the export market, τ^K units of good need to be shipped. We restrict our attention to equilibria where 1) $w^E > a^W w^W \tau^W/(a^E\lambda)$ and $w^E > a^W w^W \tau^W/(a^M\lambda)$, and 2) $w^W > a^E w^E \tau^E/(a^W\lambda)$ and $\lambda > a^E/a^M$. These conditions guarantee the existence of a complete product cycle. The first set of conditions state that the innovation quality improvement is large enough for a western quality leader to have a lower quality-adjusted production cost than an eastern firm or a multinational one step below on the quality ladder. If wages are lower in the East this condition ensures the western quality leader can still drive the lower cost competitor out of the market. Similarly, the second set of conditions state that the quality jump is large enough to allow the eastern innovator to leapfrog the western innovator or the multinational and become the global leader.

We follow the common practice and assume that to participate in pricing competition, in each

[12] For simplicity, we assume that the patent length is infinite. Generalising the model to patents of finite length is straightforward but complicates the analysis without yielding any relevant new insight.

product line, firms must pay a small fee (e.g. Howitt, 1999; Dinopoulos and Segerstrom, 2010; Akcigit et al., 2018b). Under this assumption, the profit maximising choice of the quality leader is always to charge the domestic monopoly price for domestic sales:[13]

$$p^{\kappa}(\omega,t)=\frac{\sigma}{\sigma-1}a^{\kappa}w^{K}(t), \tag{4}$$

and the export monopoly price, denoted by $(*)$, for sales in the other region:

$$p^{*\kappa}(\omega,t)=\frac{\sigma}{\sigma-1}a^{\kappa}w^{K}(t)\tau^{K}. \tag{5}$$

Notice κ represents the sector type, $\kappa=W,E,M$, while $K=W,E$ is the region indicator. The possible combinations of these two indicators are $(\kappa,K)=(W,W),(E,E),(M,E)$, that is, Western leaders producing in the West, Easter leaders, and Western leaders offshoring to the East. Western leaders producing in the East charging the domestic price to the Eastern consumers, $p^{M}(\omega,t)=\frac{\sigma}{\sigma-1}a^{M}w^{E}(t)$, while they export to the West and charge the export monopoly price $p^{*M}(\omega,t)=\frac{\sigma}{\sigma-1}a^{M}w^{E}(t)\tau^{E}$. Substituting (4), (5) and the multinational prices in the demand (2), and using it to express the total (domestic and export) monopoly profits accruing to global quality leaders we obtain the profits of Western leaders,

$$\pi^{W}(\omega,t)=\frac{1}{\sigma}\left(\frac{\sigma}{\sigma-1}\right)^{1-\sigma}(a^{W}w^{W}(t))^{1-\sigma}q(\omega,t)\left(\frac{c^{W}(t)L^{W}(t)}{P^{W}(t)^{1-\sigma}}+\frac{c^{E}(t)L^{E}(t)}{P^{E}(t)^{1-\sigma}}(\tau^{W})^{1-\sigma}\right), \tag{6}$$

the profits for Eastern leaders

$$\pi^{E}(\omega,t)=\frac{1}{\sigma}\left(\frac{\sigma}{\sigma-1}\right)^{1-\sigma}(a^{E}w^{E}(t))^{1-\sigma}q(\omega,t)\left(\frac{c^{E}(t)L^{E}(t)}{P^{E}(t)^{1-\sigma}}+\frac{c^{W}(t)L^{W}(t)}{P^{W}(t)^{1-\sigma}}(\tau^{E})^{1-\sigma}\right), \tag{7}$$

and those for multinationals

$$\pi^{M}(\omega,t)=\frac{1}{\sigma}\left(\frac{\sigma}{\sigma-1}\right)^{1-\sigma}(a^{M}w^{E}(t))^{1-\sigma}q(\omega,t)\left(\frac{c^{W}(t)L^{W}(t)}{P^{W}(t)^{1-\sigma}}(\tau^{E})^{1-\sigma}+\frac{c^{E}(t)L^{E}(t)}{P^{E}(t)^{1-\sigma}}\right), \tag{8}$$

$c^{W}(t)$, $c^{E}(t)$ are per capita expenditures and $L^{W}(t)$ and $L^{E}(t)$ are the population and labor sizes of the two regions, respectively. We choose the Western wage to be the numeraire of our economy, $w^{W}=1$.

[13]Typically in these models the quality leader charges the monopoly price when the innovation is "drastic", which implies a large λ, and the limit price with non "non-drastic" innovation, low λ. Under our assumption of costly participation, with non-drastic innovation, if the followers enter the game the leader will first charge limit price, then, after the follower has left, will revert to monopoly price. The follower has no incentives to play this game and, as a consequence, the leader can always charge the monopoly price.

3.3 Global R&D races

In each sector, incumbent leaders are challenged by entering firms that employ workers in research to discover the next best-quality version of their products. The arrival rate of innovation in sector ω at time t is $I(\omega,t)$, which is the aggregate summation of the Poisson arrival rates of innovation produced by all firms targeting ω. Each firm i can obtain an arrival rate of innovation using the following technology:

$$I_i^{\kappa}(\omega,t) = A^{\kappa}(\omega,t)^{1-\alpha} l_{Ri}^{\kappa}(\omega,t) L_R^{\kappa}(\omega,t)^{-\alpha}, \tag{9}$$

for $\kappa = W,M,E$. A^W is the R&D efficiency of Western firms, A^M is the productivity of FDI, the investment in adaptive R&D that firms must do to produce abroad, while A^E is the R&D efficiency of Eastern firms. $l_i^{\kappa}(\omega,t)$ is the R&D labour employed by firm i, of type κ, in sector ω, while $L_R^{\kappa}(\omega,t) = \sum_i l_{Ri}^{\kappa}(\omega,t)$ is the total R&D labor by firms of type κ, in sector ω. This technology implies that each firm's instantaneous probability of success is a decreasing function of the total national R&D investment in the sector, $0 < \alpha < 1$. The region-specific nature of decreasing returns in R&D can be motivated by the presence of fixed costs, such as lab equipment, by institutional and/or cultural differences, and finally by a given supply of workers with heterogeneous research abilities.[14]

The productivity term $A^{\kappa}(\omega,t)$, determines the efficiency of R&D and the structure of knowledge spillovers:

$$\begin{aligned} A^W(\omega,t) &= \gamma^W \left(\frac{q(\omega,t)}{\hat{Q}^W(t)^{\phi}} \right)^{-1} \\ A^M(\omega,t) &= \gamma^M \left(\frac{q(\omega,t)}{\hat{Q}^W(t)^{\phi}} \right)^{-1} \\ A^E(\omega,t) &= \gamma^E \left(\frac{q(\omega,t)}{\hat{Q}^E(t)^{\phi}} \right)^{-1}. \end{aligned} \tag{10}$$

R&D efficiency is lower in sectors with higher quality, indicating that innovation and technology transfer becomes increasingly challenging as $q(\omega,t)$ rises and the target of R&D becomes more complex. Moreover, R&D efficiency increases with the aggregate quality, due to knowledge spillovers. These spillovers exhibit a nuanced structure, blending local and global influences. Local spillovers stem from the aggregate quality of goods produced by firms within the same region, whereas global spillovers arise from the aggregate quality of goods produced across all regions. Assumption 1 formalises these features:

Assumption 1. *(Technology gap) R&D efficiency has the following structure:*

(a) Western innovation is more productive: $\gamma^W > \gamma^E$.

[14] See Eaton and Kortum (1999) and Impullitti (2010) for further insight.

(b) *Western innovation and FDI receive spillovers,*

$$\hat{Q}^W(t) = Q^W(t)^{\beta^W} Q(t)^{(1-\beta^W)},$$

where $Q^W(t) = \int_{\omega^W} q(\omega,t)d\omega$ *is the average quality of sectors with Western leader producing in the West,* ω^W *is the share of these sectors.* $Q(t) = \int_0^1 q(\omega,t)d\omega$ *is the aggregate global quality.*

(c) *Eastern firms receive spillovers,*

$$\hat{Q}^E(t) = Q^{E+M}(t)^{\beta^E} Q(t)^{(1-\beta^E)},$$

where $Q^{E+M}(t) = \int_{\omega^E+\omega^M} q(\omega,t)d\omega$*, is the average quality of sectors with production in the East from both Eastern leaders, with mass* ω^E*, and multinational firms, with mass* ω^M*.*

(d) *There is a local bias in knowledge spillovers:* $1/2 < \beta^W = \beta^E < 1$.

(e) *Technology diffuses via FDI allowing Eastern firm to start innovating.*

(f) *Aggregate spillovers become weaker as the economy grows:* $\phi < 1$.

This assumption establishes the key technological differences between the two regions. The main idea of this modelling strategy is that firms gain more insights from local production activities and the diverse range of sectors present locally, then from production taking place abroad.[15] Knowledge diffuses via FDI in two significant ways. First, the presence of multinational corporations in the East allows local firms to gain informal access to foreign knowledge. This diffusion process enables Eastern firms to start innovating in the sectors where new successful multinational has entered. Second, FDI strengthens the intensity of the local spillovers affecting Eastern firms, thereby improving their innovation efficiency. The local bias of spillovers, along with $\gamma^W > \gamma^E$, gives the West a comparative advantage in R&D.[16]

In order to address the "scale effect" problem affecting the first generation endogenous growth models, we impose "weak" across-sector (aggregate) spillovers as in Jones (1995).[17] Spillovers become less powerful as the aggregate quality grows, which allows us to obtain a stationary growth rate that is independent of population size. As we will see later, this solution to the scale effect problem implies that policies have only a temporary effect on growth, as the long-run growth rate is exogenous and

[15] This is consistent with the empirical evidence on the local nature of technological spillovers that we show in our empirical motivation. For a review of the empirical evidence on FDI and knowledge spillovers see Keller (2004) and Keller (2021).

[16] Higher R&D productivity γ translates implies that Western firms lead, in equilibrium, in a larger share of sectors, $\omega^W > \omega^E$. As a consequence the aggregate quality of goods produced by western firms locally is higher, $Q^W > Q^E$, which, due to the local bias of spillovers, means stronger spillovers. Thus, the local bias, reinforces the advantage in R&D efficiency produced by the higher γ.

[17] First generation Schumpeterian models have the counterfactual implications that the long run growth rate is proportional to population size.

proportional to population growth. For this reason this version of the Schumpeterian model is known as the "semi-endogenous" growth model.[18] As in the standard Schumpeterian model, the "Arrow effect" (Aghion and Howitt, 1992; Grossman and Helpman, 1991b) operates and innovation is only done by entrants, whereas incumbents have no incentives to innovate. Hence the free entry condition fully characterises the equilibrium innovation effort in the economy.[19]

Governments subsidise R&D expenditures at the rate s^K, which is region-specific. Each entrant firm chooses the amount of labour devoted to R&D, equating the expected returns to the costs. The R&D returns are $v^\kappa(\omega,t)I_i^\kappa(\omega,t)dt$, where $v^\kappa(\omega,t)$ denotes the value of a patent as discounted stream of profits while $I_i^\kappa(\omega,t)dt$ is the instantaneous probability of a successful innovation. The innovation cost is $(1-s^K)w^K(t)l_{Ri}^\kappa(t)dt = (1-s^K)w^K(t)I_i^\kappa(\omega,t)A^\kappa(\omega,t)^{\alpha-1}L_R^\kappa(\omega,t)^\alpha dt$, where we have used (9) to substitute for R&D labour l_{Ri}^κ. Free entry into R&D races equates the above benefits and costs of innovation, leading to,

$$v^\kappa(\omega,t)A^\kappa(\omega,t)I^\kappa(\omega,t)^{\frac{\alpha}{\alpha-1}} = (1-s^K)w^K(t), \tag{11}$$

for the three possible combinations $(\kappa,K) = (W,W),(E,E),(M,E)$.[20]

To derive the value of a firm, or a patent, $v^\kappa(\omega,t)$, note that a shareholder of the quality leader of type κ in sector ω, receives a dividend $\pi^\kappa(\omega,t)dt$ over the time interval dt. At the same time, the value of the patent changes by $\dot{v}^\kappa(\omega,t)dt$, while the shareholder suffers a loss of $v^\kappa(\omega,t)$ if an potential entrant succeeds in innovating, an event happening with probability $\hat{I}_\kappa(\omega,t)$, which is the total innovation by potential entrants targeting the sector. This is Schumpeterian *creative destruction*: successful innovation by entrants comes at the expense of incumbent firms. Assumption 1 implies that creative destruction is different for the three types of incumbent firms, as we will see shortly. The presence of efficient financial markets implies that the expected rate of return from holding a stock of a quality leader is equal to the riskless rate of return $r^K(t)$, which can be obtained through complete diversification. Taking limits as dt approaches zero, one arrives to the following no-arbitrage condition for the stock market: $\frac{\pi^\kappa(\omega,t)}{v^\kappa(\omega,t)} + \frac{\dot{v}^\kappa(\omega,t)}{v^\kappa(\omega,t)} = r^K(t) + \hat{I}_\kappa(\omega,t)$. In equilibrium, the dividend rate plus the rate of capital gains/losses equals the riskless interest rate plus a premium for the risk of being driven out of business by further innovation. It follows that the expected value of a firm (patent) is:

$$v^\kappa(\omega,t) = \frac{\pi^\kappa(\omega,t)}{r^K(t) + \hat{I}_\kappa(\omega,t) - \frac{\dot{v}^\kappa(\omega,t)}{v^\kappa(\omega,t)}}. \tag{12}$$

Using the free entry condition (11) we obtain equilibrium values of the different types of incumbent firms (patents):

[18]See Jones (1995), Kortum (1997), Segerstrom (1998) for different versions of this class of models.

[19]An incumbent considering investing in R&D needs to subtract its present monopoly profits from the payoff of successful innovation. It follows that the value of innovation for entrants is higher than for incumbents. With free entry, the entry cost is equal to the highest return to innovation, which implies that leaders do not find it profitable to innovate. This is the well-known Arrow *replacement effect* popularised by Aghion and Howitt (1992).

[20]We have substituted for the total R&D labour in sector ω activity κ by the total innovation arrival rate in the same sector/activity, $I^\kappa(\omega,t) = \sum_i I_i^\kappa(\omega,t)$, obtained from (9) aggregated to the sectoral level.

$$
\begin{aligned}
\frac{(1-s^W)}{M(I^W(\omega,t))} &= \frac{\pi^W(\omega,t)}{r^W(t)+I^W(\omega,t)-\frac{\dot{v}^W(\omega,t)}{v^W(\omega,t)}} = v^W(\omega,t) && \text{for } \omega \in \omega^W,\\
\frac{(1-s^E)w^E(t)}{M(I^E(\omega,t))} &= \frac{\pi^E(\omega,t)}{r^E(t)+I^W(\omega,t)+I^E(\omega,t)-\frac{\dot{v}^E(\omega,t)}{v^E(\omega,t)}} = v^E(\omega,t) && \text{for } \omega \in \omega^E,\\
\frac{(1-s^M)w^E(t)}{M(I^M(\omega,t))} &= \left(\frac{\pi^M(\omega,t)}{r^E(t)+I^W(\omega,t)+I^E(\omega,t)-\frac{\dot{v}^M(\omega,t)}{v^M(\omega,t)}} - \frac{\pi^W(\omega,t)}{r^W(t)+I^W(\omega,t)-\frac{\dot{v}^W(\omega,t)}{v^W(\omega,t)}}\right) = \tilde{v}^M(\omega,t) && \text{for } \omega \in \omega^M,
\end{aligned}
\tag{13}
$$

where $M(I^\kappa(\omega)) = A^\kappa(\omega,t)\,(I^\kappa(\omega,t))^{\frac{\alpha}{\alpha-1}}$, $\kappa = W,E,M$, is the marginal productivity of research of Western firms, Eastern firms and multinationals in sector ω. The first two lines report the values of a Western and Eastern leader respectively. The third row reports the value of a multinational firm, $\tilde{v}^M(\omega,t) = v^M(\omega,t) - v^W(\omega,t)$, which is given by the difference in the value of a quality leader when producing in the East and in the West. The government in the West subsidises innovative R&D at the rate s^W, while Eastern government subsidise both R&D and the adaptive research (FDI) at the rates s^E and s^M, respectively.

This first two conditions in (13) summarise the factors shaping the incentives to innovate in our model. The benefit of innovative R&D is pinned down by the value of the firm, or the value of a patent, and the productivity of innovation. The former is positively driven by the profits of becoming a market leader and negatively affected by creative destruction, the amount of innovation by potential entrants targeting that sector. In sectors where the leader is a Western firm, which have mass ω^W, creative destruction comes only from other Western firms, $\hat{I}_W = I^W$, as Assumption 1 implies that Eastern firms can only innovate in sectors where there is local production. In sectors with an Eastern leader, creative destruction affecting the value of an incumbent firm comes from both Eastern and Western potential entrants, $\hat{I}_E = I^E + I^W$, as the latter can innovate in any sector.

Innovation productivity is crucially shaped by the term $A^\kappa(\omega)$, which incorporates the exogenous efficiency parameter γ and knowledge spillovers, and by the curvature of the R&D technology governed by α. Here the curvature of the innovation technology introduces a trade-off which tames the Western comparative advantage in R&D. Decreasing returns α imply that concentrating all research in the West might not be globally efficient.

The third condition is free entry in FDI, where firms compare the value of producing at home with the value of offshoring production. Given their comparative advantage in innovation, Western firms, in equilibrium, acquire market leadership across a broader range of sectors. This results in higher levels of research and production in the West, leading to stronger labor demand and higher wages. Consequently, Western firms are incentivized to offshore production to capitalize on lower labor costs. The key factors influencing the offshoring decision are the labour cost differential, the *wage gap* — reflected in the profit differences, π^M versus π^W — and the disparity in innovation intensity, or the *creative destruction gap*, $I^W + I^E$ versus I^W. When producing locally, Western leaders compete only with potential Western entrants. However, offshoring exposes them to competition from both Western and Eastern entrants, increasing the risk of being technologically leapfrogged. This dynamic reduces the appeal of offshoring, as firms must carefully balance the cost savings achieved through foreign production against the heightened risk of losing market leadership due to technology diffusion.

Our framework thus adds a dynamic margin to the static choice of multinational production typical of trade models, where the decision is only driven by the gap in production cost (e.g. Arkolakis et al., 2018). Moreover, it extends the product cycle model in Helpman (1993) and the versions with FDI and multinationals (e.g. Dinopoulos and Segerstrom, 2010), allowing the poorer country to innovate and not just simply copy the foreign technology infringing intellectual property rights. Finally, and more saliently, it incorporates ideas flow brought via FDI as a key driver of international knowledge spillovers.

3.4 Labor market clearing

Labour demand in the West comes from production located within the region, covering the share of sectors ω^W, and R&D activities targeting all sectors. In the East, workers are employed in production by western multinationals for the share of sectors ω^M and by Eastern firms for the share of sectors ω^E. Additionally, labour demand for Eastern workers arises from western firms' adaptive R&D, aimed at facilitating production transfers in ω^W sectors, and from Eastern firms' innovation efforts in sectors where FDI has already taken place (ω^M and ω^E).

Substituting (4) and (5) for p^W and p^{*W}, and (10) for $A^W(t)$, we derive the labour market clearing condition in the West as

$$\ell^W = \int_{\omega^W} a^W q(\omega,t) p^{W(-\sigma)} \frac{c^W \ell^W}{P^W(t)^{1-\sigma}} d\omega + \int_{\omega^W} \tau^W a^W q(\omega,t) p^{*W(-\sigma)} \frac{c^E(1-\ell^W)}{P^E(t)^{1-\sigma}} d\omega + \int_0^1 \frac{I^{W\frac{1}{1-\alpha}}}{A^W(t)L(t)} d\omega \tag{14}$$

where $\ell^W = L^W(t)/(L^W(t)+L^E(t)) = L^W(t)/L(t)$ is the share of total EU labour force in region W, and $\bar{P}^{K(1-\sigma)} = P^K(t)^{1-\sigma} Q(t)^{-1}$ are the price indexes. Labor demand comes from production for domestic sales and for export, the first two terms on the right hand side, plus labor devoted to R&D, the third term.

In the East, we obtain

$$
\begin{aligned}
1-\ell^W &= \int_{\omega^E} \tau^E a^E q(\omega,t) p^{*E(-\sigma)} \frac{c^W l^W}{P^W(t)^{1-\sigma}} d\omega + \int_{\omega^E} a^E q(\omega,t) p^{E(-\sigma)} \frac{c^E(1-\ell^W)}{P^E(t)^{1-\sigma}} d\omega \\
&+ \int_{\omega^M} \tau^E a^M q(\omega,t) p^{*M(-\sigma)} \frac{c^W l^W}{P^W(t)^{1-\sigma}} d\omega + \int_{\omega^M} a^M q(\omega,t) p^{M(-\sigma)} \frac{c^E(1-\ell^W)}{P^E(t)^{1-\sigma}} d\omega \\
&+ \int_{\omega^E+\omega^M} \frac{I^{E\frac{1}{1-\alpha}}}{A^E(t)L(t)} d\omega + \int_{\omega^W} \frac{I^{M\frac{1}{1-\alpha}}}{A^M(t)L(t)} d\omega, \qquad (15)
\end{aligned}
$$

where $1-\ell^W$ is the share of total EU labour force in region E. Labor demand in the East arises from two main sources: production activities, which include domestic sales and exports by both Eastern leaders and Western multinationals offshoring to the East (captured by the first four terms on the right-hand side), and research activities, which comprise R&D efforts by Eastern firms and adaptive R&D by multinationals to transfer technology and establish production in the East (captured by the last two terms).

3.5 Growth and welfare

The model is closed with the law of motion for quality aggregates that determines the geography of production and aggregate growth. We briefly describe the rest of the model here and relegate a more detailed explanation, the definition of the equilibrium and further derivations to the Appendix B.1.

Consider the instantaneous utility given by

$$
u^K(t) = \frac{c^K(t)}{P^K(t)}, \qquad (16)
$$

implying that each period welfare is represented by real consumption. The price index is $P^K(t) = \bar{P}^K(t)Q(t)^{1/(1-\sigma)}$, with $\bar{P}^K(t)$ measuring the contribution of western quality leaders, multinationals and eastern quality leaders to the price index,

$$
\bar{P}^W(t) = [q^W(t)p(t)^{W(1-\sigma)} + q^M(t)p(t)^{*M(1-\sigma)} + q^E(t)p^{*E}(t)^{(1-\sigma)}]^{\frac{1}{1-\sigma}}, \qquad (17)
$$

$$
\bar{P}^E(t) = [q^W(t)p^{*W}(t)^{(1-\sigma)} + q^M(t)p^M(t)^{(1-\sigma)} + q^E(t)p^E(t)^{(1-\sigma)}]^{\frac{1}{1-\sigma}}. \qquad (18)
$$

The domestic and export prices of the three types of producers are weighted by the relative qualities $q^k(t) = Q^k(t)/Q(t)$ which measure the geographical distribution of market leadership.[21]

Aggregate quality at time t is determined by the total number of innovations from time zero to t. Its growth rate, $g(t)$, is driven by innovation performed in the West and in the East, and it can be shown to

[21] The aggregate quality of goods with Western, multinationals and Eastern leadership are functions of the quality and of the mass of each type of sectors. That is $Q^W(t) = \int_{\omega^W} q(\omega,t)d\omega$, $Q^E(t) = \int_{\omega^E} q(\omega,t)d\omega$ and $Q^M(t) = \int_{\omega^M} q(\omega,t)d\omega$.

be

$$\frac{\dot{Q}(t)}{Q(t)} = (\lambda^{\sigma-1} - 1)\left[I^W(t) + \left(q^E(t) + q^M(t)\right) I^E(t)\right] = g(t). \tag{19}$$

where $q^W(t)$+ $q^E(t)$ +$q^M(t)$=1. Since adaptive R&D from multinational firms does not directly generate innovation, the drivers of aggregate quality growth are the innovation by western leaders $I^W(t)$, which takes place in all sectors of the economy, and innovation by eastern leaders, $I^E(t)$, taking place in sectors with production in the East. Adaptive R&D affects growth only indirectly via its role as a vehicle of knowledge spillovers. Utility grows due to the impact of innovation-induced quality growth on the price index. The growth rate of utility is then

$$\frac{\dot{u}(t)}{u(t)} = \frac{1}{\sigma - 1}\frac{\dot{Q}(t)}{Q(t)}. \tag{20}$$

The intertemporal (flow) budget constraint is given by $\dot{\mathscr{A}}^K(t) = w^K(t) + r^K(t)\mathscr{A}^K(t) - c^K(t) - n\mathscr{A}^K(t) - T^K(t)$, where $\mathscr{A}^K(t)$ denotes the total assets per capita, and $T^K(t)$ is the lump-sum tax per capita that is used to finance the subsidised share of the R&D labour cost in region K. We can write the region K per-capita nominal consumer expenditure as

$$c^K(t) = w^K(t) + (r^K(t) - n)\mathscr{A}^K(t) - \dot{\mathscr{A}}^K(t) - T^K(t), \tag{21}$$

where taxes per capita are given by $T^K(t) = s^K w^K \frac{1}{L^K(t)} \int_{\omega^K} L_R^K(\omega,t)d\omega$.

The total stock of per capita assets in each region is defined as the per capita value of all businesses whose creation is financed by the consumers in that region.[22] Western households finance R&D conducted by Western firms, including the adaptive R&D required for offshoring production. As a result, they receive dividends comprising the profits of firms operating in the West and the profits of multinational firms. The total assets value in the East is the value of quality leaders from the East.

$$\begin{aligned} \mathscr{A}^W(t) &= \int\limits_{\omega^W+\omega^M} \frac{v^W(\omega,t)}{L^W(t)}d\omega + \int\limits_{\omega^M} \frac{\tilde{v}^M(\omega,t)}{L^W(t)}d\omega \\ \mathscr{A}^E(t) &= \int\limits_{\omega^E} \frac{v^E(\omega,t)}{L^E(t)}d\omega. \end{aligned} \tag{22}$$

Households' lifetime utility given by equation (1) represents the present value of the infinite horizon

[22] We assume full "home bias" in asset ownership, following the empirical evidence surveyed in Coeurdacier and Rey (2013).

path of the three components, $c^K(t)$, $\bar{P}^K(t)$ and $Q(t)$ and can be written as

$$
\begin{aligned}
U^K &= \int_0^\infty L_0^K e^{-(\rho-n)t}(\log c^K(t) - \log P(t))dt \\
&= \int_0^\infty e^{-(\rho-n)t} \log c^K(t)dt + \int_0^\infty e^{-(\rho-n)t} \log \bar{P}^K(t)dt \\
&\quad + \frac{1}{1-\sigma}\int_0^\infty e^{-(\rho-n)t}\left(\int_0^t g(\hat{t})d\hat{t}\right)dt.
\end{aligned} \tag{23}
$$

In our analysis of the different policy scenarios, we decompose the welfare effects of subsidies separating the channels operating via consumption and the geographical component of the price index, and the more intrinsically dynamic component due to quality growth. We give more detailed discussion of these channels in Section 3.6 next. We perform the welfare analysis including the transitional dynamics to fully accounting for the dynamic welfare gains brought about by innovation and policy cooperation.

Finally notice that in steady state, the growth rate is exogenous and pinned down by population growth,

$$
g = \frac{n}{1-\phi}. \tag{24}
$$

This is the typical feature of the model's semi-endogenous nature, where policies have only transitional effects and do not affect the steady-state growth rate, which is governed by population growth. Moreover, in steady state the geographical component of the price index $\bar{P}^K$ and expenditure are constants over time, so households' lifetime utility (1) becomes,

$$
\begin{aligned}
U^K &= \int_0^\infty L_0^K e^{-(\rho-n)t}(\log c^K(t) - \log P^K(t))dt \\
&= \frac{\log c^K}{\rho-n} - \frac{\log \bar{P}^K}{\rho-n} + \frac{n}{(1-\phi)(\sigma-1)(\rho-n)^2}.
\end{aligned} \tag{25}
$$

Innovation subsidies affect welfare via per-capita nominal consumption level c^K and the impact of the geographical leadership distribution on the price index $\bar{P}$. That is — since growth in the long-run is exogenous, innovation has only "level" effects on real income and consumption in the steady state. Innovation has "growth" effects along the transition, so in order to fully capture the dynamic welfare gains from innovation, the welfare measure must take into account the transitional dynamics.

3.6 Innovation externalities and the motives for R&D subsidies

To understand the effects of R&D subsidies on welfare and the determinants of the optimal level of these subsidies we need to discuss the externalities produced by innovation. Schumpeterian growth models feature several externalities originating from innovation which shape the scope for policy intervention. Understanding these external effects provides theoretical guidance for the quantitative analysis that follows. We first provide an analytical derivation of the key innovation externalities using a simplified version of our framework and then provide a heuristic discussion of the richer features that they acquire in the full model. For clarity of exposition we start with the closed economy and derive the standard externalities (e.g. Grossman and Helpman, 1991a; Segerstrom, 1998). We then move to uncharted territory and show how these externalities acquire new richer features when the economy is open to trade. The model with FDI is too complex to derive analytical insights of the key novel externalities and the related motives for subsidies. We address these new features related to FDI in a detailed discussion.[23]

A simplified framework. We take a special case of our CES preferences, where the elasticity of substitution across varieties is one. This implies that limit pricing becomes the optimal pricing strategy, that is $p = a\lambda w$, and we assume $a = 1$. Taking the wage as the numeraire, $w = 1$, log utility implies that the quantity consumed of each good is $c/p = c/\lambda$, where c is expenditure per capita. We adopt a simple R&D technology by setting $\alpha = 0$ and $A(\omega, t) = A$ constant in equation (9).[24]

We follow the procedure in Grossman and Helpman (1991a) and suppose that an external agent (a Martian) has achieved a single innovation in some product line j at time t. We perturb the market equilibrium from that period onwards, so that we preserve the original innovation path, and compute the impact on the welfare of all agents other than the one who collects the profits from the innovation (the Martian). We ignore the profits of the external innovator because innovating firms' private costs are exactly balanced by private benefits.

First, we write (1) as

$$U(t) = \int_t^{\infty} e^{-(\rho-n)(s-t)} \ln\left(\frac{c(s)}{\lambda}\right) ds + \int_t^{\infty} e^{-(\rho-n)(s-t)} \left[\log(\lambda)\Phi(s)\right] ds, \tag{26}$$

where $\Phi(s)$ is the total number of innovation successes before time t. We perturb the market equilibrium by $d\Phi(t)$ for every moment in time after time t. The effect of a marginal innovation on the welfare of agents is found by differentiating (26) with respect to $\Phi(s)$,

$$\frac{dU(t)}{d\Phi} = \int_t^{\infty} e^{-(\rho-n)(s-t)} \frac{1}{c(s)} \frac{dc(s)}{d\Phi(s)} ds + \int_t^{\infty} e^{-(\rho-n)(s-t)} \log(\lambda) ds. \tag{27}$$

The second term on the RHS of (27) is the growth effect, i.e. the marginal benefit at initial prices from consuming a newly invented higher quality product. The discounted value of this term is $\log(\lambda)/(\rho - n)$. When an innovation is first introduced it benefits consumers immediately as they can buy goods of a higher quality at the same price, but it also benefits consumers in the future as all later innovations build upon past innovations. This externality combines what Grossman and Helpman (1991b) call a *consumer surplus effect*, operating during the life cycle of the new product with what

[23] It is in general difficult to isolate the rich set of externalities motivating policy intervention in open economy endogenous growth models. For this reason, most papers typically present a simple informal discussion to guide the interpretation of the quantitative results (Akcigit et al., 2018b; Choi and Shim, 2024; Hemous et al., 2023).

[24] As typical in this class of models, a linear R&D technology implies that the model jumps directly to the steady state (see e.g Grossman and Helpman, 1991a).

Aghion and Howitt (1992) term an *intertemporal knoweldge spillover* effect which affects future consumers via later innovations. Since innovating firms do not take these effects on consumers into account, they tend to underinvest in innovation. These effects constitute motives to subsidise R&D. The consumer surplus effect is not specific to endogenous growth theory, it is also present in any static model where innovation reduces the price of the good it targets with no future effects.[25] The intertemporal spillover effect is the new key feature brought about by endogenous growth theory.

The first term on the right side of (27) captures the loss in aggregate spending as the effect of the marginal innovation. Added innovation reduces the profits of agents (other than the innovator) and their spending falls. This is the *business-stealing* effect produced by the very nature of Schumpeterian competition (Aghion and Howitt, 1992). When a quality laggard firm successfully innovates, it drives the incumbent firm in its product line out of business. The appropriation of the incumbent firm's monopoly profits reduces the income of the households owning those firms, thereby reducing aggregate consumption and lowering the profits of the other leading firms. The innovating firm does not take this into account and is therefore bound to over-invest in R&D. This is a motive for taxing innovation.[26]

To derive this effect, first note that aggregate spending $c(s)$ equals total income (wages plus profits) minus the spending/investment in R&D, $c(s) = 1 + \Pi(s) - I(s)/A$.[27] Since we take the rate of innovation to be unaffected by the external innovation, the changes in expenditures triggered by the latter equal the change in profits. Profits are $\Pi(s) = c(s)(\lambda - 1)/\lambda$. If no other innovation takes place before time s, the economy loses the profits $c(s)(\lambda - 1)/\lambda$ at time s. This profit loss in the innovating industry has also a multiplier effect on the profits of other firms in the economy, as it induces a drop in aggregate spending, which reduces sales in all other industries. The aggregate change in profits is then, $d\Pi(s)/d\Phi(s) = -c(s)(\lambda - 1)/\lambda + (dc(s)/d\Phi(s))(\lambda - 1)/\lambda$. Since, $dc(s)/d\Phi(s) = d\Pi(s)/d\Phi(s)$ from the budget constraint above, the expected reduction in spending at any time $s \geq t$ is $dc(s)/d\Phi(s) = -(\lambda - 1)c(s)e^{-I(s-t)}$. This expression takes into account the probability of no other innovation success occurring between t and s, with I being the equilibrium arrival rate of innovation.[28] Substituting this into (27), we obtain the external effects of innovation on welfare:

$$\frac{dU(t)}{d\Phi} = \underbrace{\frac{\log(\lambda)}{\rho - n}}_{\substack{CS+IS \\ (+)}} - \underbrace{\frac{\lambda - 1}{I + \rho - n}}_{\substack{BSE \\ (-)}}. \tag{28}$$

[25] This is present in static models of strategic industrial policy (e.g. Spencer and Brander, 1983; Eaton and Grossman, 1986; Haaland and Kind, 2008).

[26] Another motive for taxing R&D comes from the market structure. Markups produce not only a static distortion, as goods are under-provided but also a dynamic one, since too little inputs devoted to production implies that too much of them are allocated to R&D (e.g. Denicolo' and Zanchettin, 2014). To simplify the exposition we do not discuss this in detail; we also find it to be second order quantitatively.

[27] This is another way of writing (21), which allows us to simplify the algebra of computing the external effects.

[28] The arrival rate of innovation follows a Poisson process, so the time duration of R&D races is exponentially distributed with parameter I, the equilibrium arrival rate. Therefore, the probability that a further innovation occurs between time t and s is $1 - e^{-I(s-t)}$.

The consumer surplus and intertemporal knowledge spillovers are positive externalies and therefore represent a motive for subsidising innovation while the business stealing effect is a negative externality and motivates a welfare maximising planner to tax innovation. Although our scope here is to provide theoretical insights and not necessarily a fully closed form expression for the externalities, the latter is attainable for this simple model. As shown in the appendix, using a simple linear R&D technology we obtain $I = A(\lambda - 1) - (\rho - n)$.

We now turn to the open economy, abstracting from FDI. To gain insight, we analyse a simple version of our open economy which allows an easy comparison with the closed economy. We assume that the two countries differ in their market leadership due to differences in some primitives. The specific nature of the differences in primitive parameters is not relevant for the analysis. To facilitate comparison with the closed economy and focus on the impact of business stealing on profits, we follow Impullitti (2010) and abstract from labour market effects, assuming that once a firm innovates, it can decide to locate production anywhere at no additional cost. Thus, the labour market is global, ensuring that wages are equalised across both countries. As in the case of a closed economy, we normalise the wage by taking it as the numeraire.

We can write the expenditures in the two countries as follows: $c^W(s) = (1 + \Pi(s))\hat{\omega} - I^W(s)/A$ and $c^E(s) = (1 + \Pi(s))(1 - \hat{\omega}) - I^E(s)/A$, where the first term on the right hand side represents the labour income of production workers, $\hat{\omega}$ is the share of industries with West leadership and profit per sector, $\Pi(s) = (c^W(s) + c^E(s))(\lambda - 1)/\lambda$, depends on global demand. We proceed as above to determine the welfare impact of an external innovation. We assume that an external agent successfully innovates on a product line where the incumbent leader is an Eastern firm and focus on the impact of this innovation on Western welfare.[29] This scenario allows us to highlight the key differences between the closed and the open economy.

The consumer surplus and intertemporal spillovers parts are identical, except that now in the open economy, consumers from both countries benefit from the higher quality goods introduced by each innovation, no matter where the innovator comes from. The business stealing effect instead, changes substantially. There is no direct loss in profits for the West, as none of its leading firms is replaced by the external innovation. Profits are shifted from the Eastern leader to the external agent and the only profit loss for Western firms operate via the multiplier effect of the reduction in Eastern expenditures. The Eastern country instead experiences both the direct profit shifting effect due to leadership loss and the indirect effect via the expenditure multiplier.[30] To facilitate comparisons with the closed economy we assume that the two countries are symmetric and that the open and closed economies have the same steady state innovation path.[31] Following the same procedure as in closed economy we obtain,

[29] The case in which the external agent innovates on a product line with West leadership has an impact on the Western economy similar to that in closed economy.

[30] We are focusing only on how the open economy affects the external impact of innovation on profits, abstracting from the potential effects on the terms of trade, the relative wages. This could produce a further benefit for the West, in our example, although this disappears in the symmetric countries case which we analyse below.

[31] Recall also that the innovation by the external agent does not change the original innovation path of the economy.

$$BSE^W_{open} = \int_t^\infty e^{-(\rho-n)(s-t)} \frac{1}{c^W(s)} \frac{dc^W(s)}{d\Phi(s)} dt \quad = \quad \left(\frac{\lambda-1}{2I+\rho-n}\right) \frac{\lambda-1}{2\lambda} < BSE^W. \tag{29}$$

In the open economy then, the business stealing effect of innovation is weaker because the direct impact of innovation on the profits of non-innovating firms is borne mostly by the foreign country. This provides a key insight on the welfare impact of R&D subsidies, which will be the core of our analysis that follows. If we replace the external innovator with a Western firm, our results suggest that the business stealing effect of innovation is weaker for the West, as part of it, the direct profit-shifting is offloaded to the other country. Thus there is a *strategic motive* which implies that policy makers are less likely to tax innovation in open economy, if they behave uncooperatively.

The methodology used to derive the innovation externalities based on the experiment of an external innovator does not allow for the profit shifting effect, typical of the strategic trade and industrial policy literature (e.g. Spencer and Brander, 1983; Eaton and Grossman, 1986; Leahy and Neary, 1997). That literature utilises partial equilibrium models with only one firm per country competing oligopolistically. The business stealing effects consists of shifting the additional profits brought about by innovation from the foreign to the home firm. This profit-shifting increases home welfare, which creates a potentially larger externality for a coordinated policy maker to correct. Our method based on the external agent shows that this is not an innovation externality that the government should act to correct, but a pure strategic motive to subsidise innovation by national firms. In our quantitative analysis of the welfare impact of subsidies, both types of strategic motives will play a role, the direct profit-shifting and the general equilibrium business stealing derived in (29). They both combine to give a scenario where uncoordinated subsidy rates in the open economy may in fact be too high relative to what a coordinated planner would choose.

Although the simple model does a good job capturing most aspects of the innovation externalities embedded in our full model, it misses one key feature, the role of *international knowledge spillovers*. R&D technology (10) implies that, if intertemporal knowledge spillovers are to some degree global, innovation by one country improves the R&D efficiency in the other country. This gives rise to an externality for which a cooperative policy maker must account.

International cooperation. Policy cooperation corrects the distortions produced by the strategic motive and by the two positive innovation externalities.[32] The global policymaker's role is to maximise global welfare. They are more likely to tax R&D optimally in order to correct for the distortions produced by the strategic motive. However, the fact that innovation by a firm in one country affects growth and innovation technology in the other through international spillovers, makes the global policymaker more likely to subsidse R&D. It follows that cooperative R&D subsidies can be,

i. lower than uncooperative subsidies if the strategic motive dominanates;

[32] The domestic business stealing effect does not play a role in cooperative policy.

ii. higher than uncooperative subsidies if consumer surplus and knowledge spillovers dominate.

FDI, knowledge spillovers and the motive for subsidies. How does FDI impact the motives to set R&D subsidies cooperatively? Technology (10), carries two new distortions that the global policy maker wants to correct. First, Western firms' underinvestment in innovation due to international knowledge spillovers becomes larger. Due to FDI, Eastern firms enjoy stronger spillovers, as they have access to larger chunk of the advanced region's stock of knowledge. Through this margin, the presence of FDI produces an additional reason for the global policy maker to subsidise Western innovation. In addition to this, FDI's role of carrying knowledge spillovers across borders implies that there is underinvestment in adaptive R&D from a global perspective. This second margin suggests that the cooperative policy should also include a new instrument, a subsidy to FDI.

The external effects discussed above have been derived in a framework where countries are symmetric. In our full model economy, countries are structurally different in their R&D efficiency, which produces a crucial difference in the growth externality, the knowledge spillovers. Since $\gamma^W > \gamma^E$, innovation is more productive in the West which, as we will see later, implies that Western firms will be the quality leaders in a larger set of industries. Hence, knowledge spillovers $\hat{Q}^K$ in (10) will be larger for the West, thereby leading to a larger underinvestment in innovation for firms in this region. Consequently, cooperative policy has the incentive to subsidise West R&D more. On the other hand, the innovation technology (9) features a local externality, which makes the productivity of a firm's R&D in a region/sector declining in the total amount of R&D labour devoted by firms in the same region/sector. The smaller is α, which regulates the strength of this externality, the more the global planner wants to diversify R&D and subsidise innovation in the East more than in the West. This *diversification* channel implies that the global policy maker might want to subsidise firms in the two regions at different rates and that the subsidy rate in the West might not necessarily be higher than in the East.

In the quantitative analysis we use these theoretical insights to interpret our numerical results. We follow the decomposition of welfare suggested in (23) and separate the impact of different policy scenarios into the component operating via changes in expenditures, which embeds the distortions due to the strategic motive and the components operating via the effects of innovation on the price level where the growth rate and therefore knowledge spillovers operate.[33] The externalities governing the diversification channel can operate both via expenditure or prices, so they are more difficult to measure but their role can be easily uncovered by the differences in the cooperation subsidies between the two countries.

[33] For completeness we also report the geographical component of the price index, which embeds the consumer surplus effect, as it carries the impact of innovation on prices abstracting from the knowledge spillovers. Its role in shaping the welfare impact of subsidies is similar to that of knowledge spillover.

4 Quantitative analysis

Next, we calibrate the model to EU data and perform a set of quantitative exercises. We compute the optimal cooperative R&D subsidies, where a planner chooses subsidy rates for each country, s^W and s^E, to maximise joint EU welfare. In this exercise, we consider varying horizons of policymakers.[34] We then turn to explore the quantitative effect of FDI as a vehicle for endogenous knowledge spillovers. We do this firstly by studying how the optimal R&D subsidies and welfare gains vary with the efficiency of the FDI technology γ^M, then secondly through an exercise where the EU planner can optimally choose the FDI subsidy s^M, in addition to s^W and s^E.

4.1 Calibration

We calibrate the parameters of the model to match empirical regularities of the EU economy in the 2005-2016 period. The European Union, EU28, consists of the two groups: EU15 (old members, the West) which includes Belgium, France, Germany, Italy, Luxembourg, the Netherlands, Denmark, Ireland, the U.K., Greece, Portugal, Spain, Austria, Finland and Sweden, and the EU13 (new members, the East) which includes Cyprus, Croatia, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Slovakia, Slovenia, Bulgaria and Romania.

We focus on moments generated by the model's steady state. There are 17 parameters. Three of them, ρ, n, ℓ^W, and the two innovation R&D subsidies, s^W and s^E, are assigned their values directly using data from Eurostat and the OECD. For lack of data targets we assume $s^M = 0$ in the baseline parametrisation. We set ρ (equal to the interest rate r in the steady state) to 0.0404 to match the average Maastricht Treaty EMU convergence criterion series related to the interest rates for long-term government bonds in the EU. Next, we select the value for n to match the average population growth rate in the EU of 0.44%. We calculate the West relative labour force size (ℓ^W) of 0.801 from the population data. Finally, we use the values for the subsidies of the two regions of 12.2% and 9.7% for the West and the East, respectively, which are the average values of the OECD B-index (large firms) measuring the business tax subsidy rates on R&D expenditures in the 2005-2016 period, obtained from the OECD Main Science and Technology Indicators Database. In the benchmark calibration, the iceberg trade costs for both West and East are taken to be unity.[35] We normalise the production efficiency a^W to one. We set the elasticity of substitution σ to 3.2, matching the most conservative empirical estimates of the substitution elasticity across industries in Feenstra et al. (2018).[36]

[34]This amounts to solving for the transition path from a policy change and then considering subsets of the real consumption transition, capped at the policy horizon of interest. Longer subsets of this path pertain to more forward-looking policymakers. We allow the EU policymaker to re-optimise their choice of subsidy for each horizon under consideration.

[35]We take free trade as the benchmark and explore the role of trade cost later with robustness exercises.

[36]Using insights from the new generation of quantitative trade models (e.g. Dekle et al., 2008), Feenstra et al. (2018) find that the median micro-elasticity of substitution across industries lays between 3.2 and 4, depending on the econometric specification used.

The remaining 9 parameters are calibrated internally in a way that best matches the model's steady state to empirical facts of the EU economy — the long-run averages for the old and the new EU member states. Since we calibrate a general equilibrium model, most model-implied moments are a function of all parameters jointly, meaning that there is typically no one-to-one mapping between parameters and moments. An exception is the parameter governing the strength of knowledge spillovers in the R&D technology, ϕ. Our model counterpart of the growth rate in the data is $n/((\sigma-1)(1-\phi))$, which we discipline to match the MFP growth rate of 0.66%. Given that we set $\sigma = 3.2$ and $n = 0.0044$ externally as discussed above, this moment uniquely identifies our baseline value of $\phi = 0.69$.

Before turning to detail the particulars of the data target sources, we now give some discussion of identification of the remaining 8 internally-calibrated parameters. Despite the fact that these parameters do not map one-to-one with moments, some data targets contain more information about particular parameters than others. We leverage data on sectoral leadership shares across the three types of firms (ω^W, ω^E, ω^M) to inform the values of the R&D efficiency parameters γ^W and γ^E. As γ^W rises relative to γ^E, firms from the West become more likely to successfully innovate. This skews the steady state sales distribution towards the West, lowering that in the East, with the residual market share being held by Western multinationals. We then utilise the wage rate in the East relative to the West to inform the FDI adaptive R&D efficiency parameter γ^M. Given the distribution of market shares, and the 'creative destruction gap', a higher value of γ^M tends to increase the overall level of labour demand in the East, putting upward-pressure on wages. Two measures of East innovation intensity shed light on the parameters a^E and a^M. Firstly, the Eastern share of labour dedicated to R&D efforts contains information on the efficiency of the manufacturing productivity of East firms and Western multinationals jointly. Secondly, the East ratio of R&D spending/GDP can be used to disentangle the two, given that spending efforts are financed by firms' country of origin. The R&D spending/GDP ratio in the West relates to the marginal benefit of innovative efforts; it can be used to inform the value of α, which governs the effect of geographical R&D concentration on the probability of success. Lastly, leveraging the asymmetry of the two regions in the model, two moments are informative about the degree of local bias in spillovers $\beta^W = \beta^E = \beta$ and the quality step size λ. Specifically, we compute the numerical steady state elasticity of local innovative efforts to local R&D subsidisation in each region.[37] Given that we consider local R&D responsiveness from local subsidies, a larger value of β can give a larger elasticity. Similarly, bigger values of λ will tend to give a stronger responsiveness to innovation incentives.

Table 2 reports the parameter values and model's fit. Although the model is quite stylised, it matches several of the key moments well. Finally, we briefly discuss the sources of the data used in generating the target moments. We measure the Eastern relative wage as the relative average net earnings in PPP as reported by Eurostat for the 2005-2016 period, giving a value of 0.61. Our 0.66% multi-factor productivity growth rate is an average reported by the OECD for the set of countries we

[37] Practically, we compute a one-sided numerical derivative of I^κ with respect to s^κ for $\kappa \in \{W, E\}$ as an input into the elasticity calculation.

Table 2: Calibration summary

External parameters	Value	Source
Interest rate ($r = \rho$)	0.04	Eurostat, 2001-2013
Population growth rate (n)	0.44%	Eurostat, 1961-2013
R&D subsidy, West (s^W)	12.2%	OECD, 2011
R&D subsidy, East (s^E)	9.70%	OECD, 2011
Relative labour size, West (l^W)	0.80	Eurostat, 2015
Utility f-n parameter (σ)	3.21	Feenstra et al. (2018)
Calibrated parameters	Value	
Innovative R&D productivity parameter, West (γ^W)	0.52	
Innovative R&D productivity parameter, East (γ^E)	0.41	
Innovative R&D productivity parameter, MNE (γ^M)	0.27	
Manufacturing productivity, East (a^E)	1.20	
Manufacturing productivity, East (a^M)	1.56	
Spillover parameter (β)	0.51	
Quality jump size (λ)	2.03	
Decreasing returns (α)	0.55	
Spillover (ϕ)	0.69	
Moments	Data (Model)	Source
East relative wage (w^E)	0.60 (0.56)	Eurostat, 2015
MFP growth rate	0.66% (0.66%)	OECD, 2005-2016
Share of sectors, Western leadership (ω^W)	91% (90%)	OECD, 2005-2016
Share of sectors, Eastern leadership (ω^E)	7% (6%)	OECD, 2005-2016
Share of sectors, MNE leadership (ω^M)	2% (4%)	OECD, 2005-2016
West R&D expenditure/GDP	3.87% (2.35%)	Eurostat, 2015
East R&D expenditure/GDP	2.12% (1.58%)	Eurostat, 2015
West share of labour in R&D	3.13% (3.11%)	Eurostat, 2015
East share of labour in R&D	2.22% (3.48%)	Eurostat, 2015
West innovation elasticity to subsidy s^W	[0.7, 3.5] (1.00)	Akcigit et al. (2018a)
East innovation elasticity to subsidy s^E	[0.7, 3.5] (1.03)	Akcigit et al. (2018a)

consider over our sample period. To construct our sectoral leadership shares for West and East, we consider the regions' output shares in total EU output. To construct these, we leverage the OECD Analytical Activity of Multinational Enterprises (AMNE) database, which provides insights on the role of multinational enterprises in the global economy, as that it includes information on output of countries according to ownership of the firms. After excluding the output of third-countries-owned enterprises, as well as the output of Eastern-owned enterprises in the West – which is negligible – , we calculate the share of sectors with Western leadership (ω^W) as the share of output of western-owned firms in the West in the total EU28 output. Our calculations suggest that Western European firms account for 91% of EU output. We calculate the total share of industries with Eastern leadership (ω^E) as the share of output of Eastern-owned firms in the East in the total EU28 output which amounts to 7% of the EU economy. The residual ($1-\omega^W-\omega^E$) represents the share of industries with multinational subsidiary firms production in the East (2%).

Our measures of R&D investment (expenditure) as a share of GDP are found to be 3.87% for the West and 2.12% for the East in the sample period. These values are obtained from Eurostat as the 2005-2016 averages of the GDP shares of expenditures on intellectual property products (part of gross capital formation), including software, R&D, and entertainment, literary, and artistic originals. The average share of scientists and engineers in total employment — the R&D labour share — take values of 3.13% and 2.22% for the old and the new member states, respectively (Eurostat, 2005-2016). We take values from the empirical literature for the innovation elasticity to subsidies. As discussed by Becker (2015), most literature studies the quantitative effects of tax credits on innovation and not the effect of direct subsidies. Subsidies' effects are mostly investigated in terms of the crowding-out effect of private investment. Akcigit et al. (2018a) investigate the R&D elasticity with respect to personal and corporate income taxes. Both at the micro (firm and individual) and macro (state) levels, taxes affect the amount, quality and the location of investment activity. Focusing on the response in the number of patents to the change in corporate and personal taxes, micro and macro estimates range from -0.7 to -3.5, which we use as our target.

4.2 Optimal policy cooperation

We analyse a cooperation scenario that we call *harmonised subsidies*, where a global policy maker chooses separate rates for the West and the East in order to maximise the joint welfare of the two regions. In our analysis we rule out ex-post side payments and compare welfare outcomes with those under the subsidies observed in the data. We first conduct the analysis assuming no FDI subsidies, introducing this extra instrument in later analysis. For all experiments, the welfare analysis is conducted taking into account the transition path produced by the changes in subsidies across scenarios. In computing optimal cooperative subsidies, the EU policy maker solves

$$(s^W_{co}, s^E_{co}) = \arg\max \left\{U^{EU}(s^W_{co}, s^E_{co})\right\},$$

where $U^{EU} = U^W + U^E$ is the union welfare and co subscripts stand for the cooperative scenario. Welfare gains from cooperation are reported in terms of compensating variation. If cooperation is implemented at time 0 and is a permanent policy change, the compensating variation χ is the change in real consumption such that,

$$\int_0^T e^{-(\rho-n)t} \log\left(\frac{c_{co}^K(t)}{P_{co}^K(t)}\right) dt = \int_0^T e^{-(\rho-n)t} \log\left((1+\chi)\frac{c_o^K(t)}{P_o^K(t)}\right) dt, \tag{30}$$

where T is the horizon of the policy evaluation and o subscripts stand for without coordination (observed data subsidy rates). Equation (30) states that households in the noncooperation scenario would need to receive χ additional consumption for each period between 0 and T in order to be as well off as in the cooperation scenarios. The analysis of the transitional dynamics allows us to consider both short, medium and very long policy horizons. We first present the results with infinite policy horizon then we explore shorter horizons.

Solution method. The solution for the transition subsequent to a policy change utilises a shooting-type algorithm in a similar spirit to Spencer (2022). We solve for the pre and post-reform steady states, which provide start and end points for the simulation respectively. The transition is then mapped using finite differences. We conjecture the time paths needed for forming the firms' value functions, which are inputs in iterating backwards from the final steady state. We then iterate forwards on the laws of motion for the relative qualities of the two countries, solve the households' problems, check the distances from the equilibrium conditions being satisfied and update accordingly until convergence. More details are given in the Appendix C.

Cooperative policy. In Table 3, we report the harmonised R&D subsidies and the gains from this cooperation scenario with respect to the observed subsidies, when the policy horizon is very long, $T = \infty$. Figure 1 shows how these outcomes are affected by the policy horizon, as we as the transitional dynamics of some key variables. There are four important outcomes that emerge.

i. The global policy maker incentivises Western firms' innovation with a 31% subsidy, and heavily taxes Eastern firms' innovation.

ii. Lifetime consumption increases by 4.5% for the union as a whole, with the full transition as the policy horizon. The West captures a significantly larger share of these welfare gains. With shorter policy horizons the East gains more than the West.

iii. The welfare gains are primarily driven by the growth engine of the economy—intertemporal knowledge spillovers.

iv. The welfare gains are decreasing in the cost of FDI.

The global policy maker wants Western firms to innovate more and Eastern firms less. Since the West is the largest region, the increase in the Western subsidy implies that the average weighted subsidy in the union increases, thereby leading to more innovation and a faster growth rate. Given that the long-run growth rate is exogenous, the growth effect of subsidies is realised only along the transition to the new steady state, as shown in Figure 1a. The higher subsidy for Western firms boosts growth in the aggregate quality of the goods produced by these firms in the West, Q^W, as well as in the quality of the goods produced by their multinational affiliates in the East, Q^M. Taxing innovation in the East reduces the quality growth of goods produced by these firms, Q^E. Aggregate growth under the cooperative subsidies is above its baseline path for approximately twenty years along the transition to the new steady state. The result is driven by the increase in growth of Western-led industries, induced by the R&D subsidy, offsetting the deceleration of the growth in Eastern-led industries. The changes in the West dominate since it holds the majority of the market share in our calibrated economy.

Table 3: Gains from policy cooperation

	Baseline (γ^M)			$2\gamma^M$			$3\gamma^M$		
	s^W	s^E	s^M	s^W	s^E	s^M	s^W	s^E	s^M
Observed (s^W_o, s^E_o)	0.12	0.10	0.00	0.12	0.10	0.00	0.12	0.10	0.00
Harmonised (s^W_{co}, s^E_{co})	0.31	-0.99	0.00	0.41	-0.97	0.00	0.43	-0.81	0.00
	W	*E*	*EU*	*W*	*E*	*EU*	*W*	*E*	*EU*
Welfare gains	0.040	0.005	0.045	0.046	0.021	0.066	0.046	0.031	0.078
Strategic motive	-0.009	-0.044	-0.052	-0.017	-0.043	-0.060	-0.020	-0.035	-0.054
Consumer surplus	-0.002	-0.002	-0.003	-0.003	-0.003	-0.006	-0.003	-0.003	-0.007
Intertemporal spillovers	0.050	0.050	0.101	0.066	0.066	0.132	0.070	0.070	0.139

Notes. All calculations take the transitional dynamics into account and the welfare effects are in compensating variation as (30) with $T = \infty$. The FDI subsidy is kept constant at zero in all scenarios. Numbers are prior to multiplication by 100.

Why does the planner want more growth? Recall that Assumption 1 implies that the West is the most R&D efficient country and the major source of idea flow across countries via its FDI activity. As a consequence, not only are Western firms more productive themselves in innovation, but their offshoring activities make Eastern firms' innovation more efficient as well. These features make Western innovation much more valuable for the union as a whole. The large cooperation subsidy for the West and the large tax for the East reflect this structural asymmetry. As such, the cost of concentrating R&D in one region, coming from local decreasing returns in innovation, α in the R&D technology (9), is more than than compensated by the gains from subsidising the most innovation efficient region and the key source of international knowledge spillovers.

Both regions gain from cooperation but the West gains substantially more than the East. Although both regions share the gains produced by the higher growth rate of aggregate quality, under cooperative subsidies the West innovates more and so its firms capture a greater share of the global market. This can be seen in Table 3, where the losses from the strategic motive are smaller for the West but also in

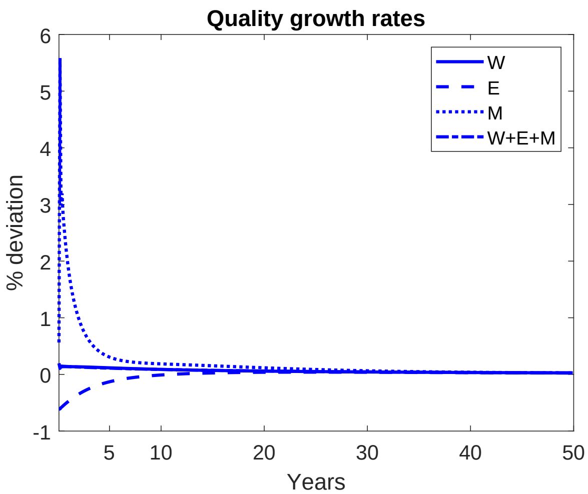
Figure 1a which shows that differential growth rate of quality of the goods produced in the two regions along the transition. Q^W, Q^E, and Q^M in fact embed the leadership shares ω^W, ω^E and ω^M, that are differentially affected by the decision of the policy marker to heavily subsidise Western and tax Eastern firms. The most remarkable change is the decision of Western firms to move more production to the East which leads to a reduction of ω^W to 0.79 from its calibrated value of 0.91 and an increase of ω^M from 0.04 to around 0.13. The share of sectors with Eastern leadership remains largely unchanged. The intensified offshoring activity significantly boosts profits for Western firms, as they benefit from lower labour costs associated with overseas production. This, in turn, contributes to greater overall welfare gains for the region.

The time horizon considered by policymakers in determining the optimal cooperative policy plays a significant role. As shown in Figure 1c, for short and medium policy horizons (less than 30 years), welfare gains are greater for the East compared to the West; over longer horizons, this trend reverses. This dynamic can be attributed to the structure of R&D subsidies, which are financed independently by each country. While Western households incur substantial costs to subsidise national firms, Eastern households benefit from the transfers generated through innovation taxation, resulting in higher Eastern consumption under cooperation over the short and medium term. However over time, the West's stronger innovation performance and increased global market share — driven by more intensive offshoring — shift the distribution of welfare gains in their favour in the long term.

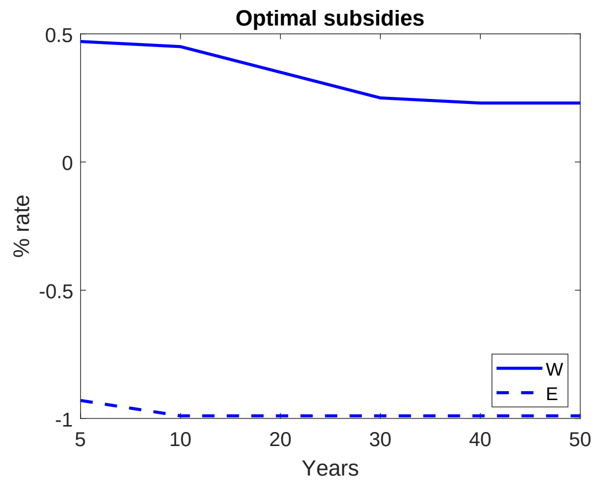
For both regions, Table 3 highlights that the primary driver for coordination is the internalisation of intertemporal spillovers. In our open economy setting, knowledge flows across regional borders, amplifying the benefits of subsidising innovation. R&D conducted in one region increases the likelihood of future innovation within its borders but also globally. These cross-border spillovers exacerbate market failures of innovation in an open economy, resulting in a greater underinvestment in innovation. The EU policymaker steps in to address this imbalance. Ultimately, the benefits of temporarily accelerating growth outweigh the potential drawbacks of distortions caused by the strategic use of subsidies.

There are losses via the consumer surplus channel, albeit negligible. Recall that this channel operates via the geographical distribution of the price index, $\bar{P}^W$ and $\bar{P}^E$ defined in (17) and (18), which are weighted averages of the prices in the three types of sectors. The weights are the relative qualities of the different types, which are an expression of the leadership shares. Cooperation decreases the share of sectors with production in the West and increases the share of sectors offshored by Western multinationals. Although wages are lower in the East, multinational firms are less productive from a manufacturing perspective than Eastern and Western firms in our calibration ($a^M > a^E > a^W$). As such, the reallocations in market shares result in a slight increase in the price indices. Note however that the incentives for increased FDI remain, given that lower Eastern innovation rates results in less creative destruction and a higher value of discounted profits from offshoring.

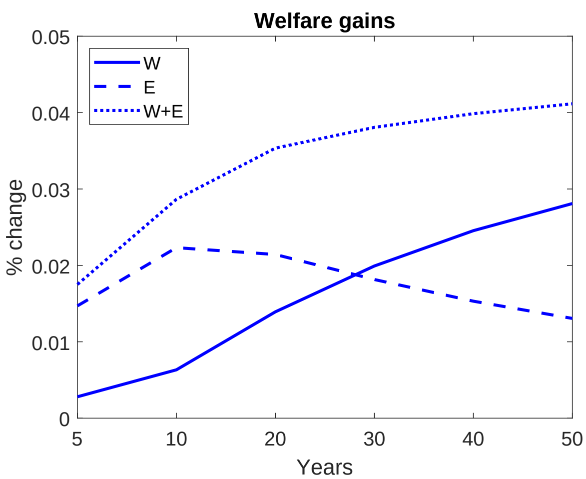
Figures 1c and 1d indicate that the benefits arising from the spillover channel grow with the policy horizon. This result stems from the inability of current innovators to internalise how their success



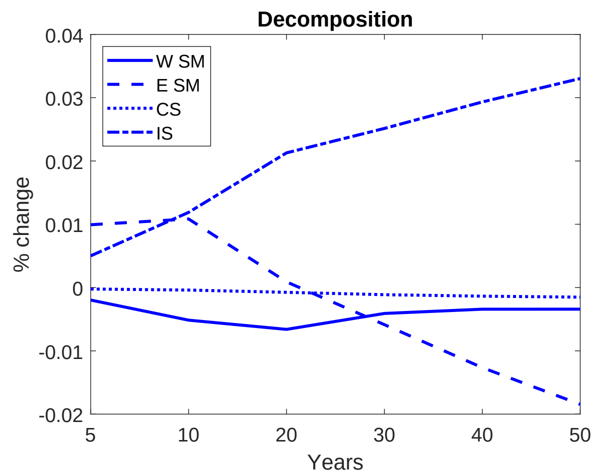
(a) Growth under cooperative subsidies



(b) Cooperative subsidies (policy horizons)



(c) Gains from cooperation (policy horizons)



(d) Gains decomposition (policy horizons)

Figure 1: Transitional dynamics dynamics and policy maker horizon

Notes. This figure shows the deviation from the calibrated steady state of moving from the observed to the coordinated subsidies. Panel a) shows the transitional dynamics of growth rate of Q, Q^W, Q^M and Q^E under cooperative subsidies as deviation from the baseline. Panel b) reports the cooperative subsidies for different policy maker horizons. Panels c) and d) show the gains from cooperation and their decomposition for different policy horizons. Numbers are all prior to multiplication by 100.

benefits future innovation. A far-sighted policymaker recognises that this market failure becomes more significant when future innovation and growth are considered, prompting a stronger inclination to subsidise innovation over the long term.

Finally, we provide some discussion of the quantitative role of FDI, through changes in the γ^M parameter. Multinational activity facilitates the exchange of ideas across regions, heightening the EU policymaker's need to address the market failure stemming from the geographical dimension of knowledge spillovers. Consistent with this, our findings show that the easier it is to transfer technology abroad (higher γ^M), the greater the gains from cooperation. Table 3 highlights the effects of doubling and tripling the efficiency of FDI. Enhanced efficiency in adaptive R&D results in higher cooperative subsidies for the West and lower taxes for the East. The reasoning is straightforward: the global policymaker seeks to encourage more innovation in the West, the primary source of cross-country knowledge flows, while simultaneously reducing taxes in the East, where stronger spillovers make innovation more effective. When FDI becomes cheaper, knowledge flows more rapidly from West to East. These accelerated and more robust spillovers significantly increase the gains from cooperation, demonstrating the critical role of FDI in maximising global welfare.[38]

Optimal innovation and FDI subsidies. The finding that higher adaptive R&D efficiency significantly amplifies the gains from coordination highlights the importance of exploring FDI subsidy policies as a complementary tool to innovation-focused strategies. Thus far, our analysis has centered on addressing the externalities produced by innovation, assuming no government support for adaptive R&D. However, firms do not account for cross-border knowledge spillovers from FDI when making offshoring decisions, potentially leading to underinvestment in knowledge transfers through FDI. This market failure provides a strong rationale for policy intervention. In addition to the *innovation policy* – the R&D subsidy analysed so for – we introduce an FDI subsidy, s^M, to address this inefficiency. A subsidy to FDI can be viewed as a more conventional tool of *trade policy*, as it affects the cost of multinational activity without direct implications for innovation.[39] With a few exceptions (e.g. Akcigit et al., 2018b) innovation and trade policies are typically analysed separately, in different models. Our framework facilitates a joint analysis and permits a decomposition of the their specific contribution to the welfare gains from international policy cooperation.

Table 4 presents the gains from different cooperative subsidy strategies. The first column reports the gains from cooperation in R&D subsidies alone, reflecting our baseline results from Table 3. The second column shows the gains from cooperating solely on the FDI subsidy, with R&D subsidies held at their observed levels. The third column shows the outcomes when both R&D and FDI subsidies are jointly chosen cooperatively. Two key insights emerge from these results. First, cooperation on both R&D and FDI subsidies leads to significantly larger gains quantitatively for both regions compared

[38] In an earlier version of the model (Borota et al., 2022), we demonstrated that eliminating FDI can significantly alter the sources of gains from cooperation. In a comparable setup with "semi-endogenous" but no FDI, the primary driver of these gains is the internalization of the strategic motive.

[39] Recall that the adaptive R&D needed to move production abroad does not have any impact on growth.

Table 4: Gains from cooperation: R&D vs. FDI subsidies

	Subsidy Instrument Scenario		
	(1) R&D only	(2) FDI only	(3) Jointly
s^W	0.31	0.12	0.26
s^E	-0.99	0.10	-0.78
s^M	0.00	0.59	0.89
W **welfare gains**	0.040	0.007	0.050
Strategic motive	-0.009	0.000	-0.005
Consumer surplus	-0.002	-0.001	-0.008
Intertemporal spillovers	0.050	0.008	0.063
E **welfare gains**	0.005	0.017	0.046
Strategic motive	-0.044	0.010	-0.009
Consumer surplus	-0.002	-0.001	-0.008
Intertemporal spillovers	0.050	0.008	0.063
EU **welfare gains**	0.045	0.023	0.096
Strategic motive	-0.052	0.010	-0.015
Consumer surplus	-0.003	-0.002	-0.016
Intertemporal spillovers	0.101	0.016	0.126

Notes. Column (1) reports the gains from cooperation in the model with FDI, where the FDI subsidy is zero. Column (2) reports the gains when only the FDI subsidy is set cooperatively and the R&D subsidies in each region are kept at their observed level. Column (3) reports the gains when both R&D and FDI subsidies are chosen cooperatively. All gains are computed with respect to observed subsidies and accounting for the transitional dynamics with $T = \infty$ and prior to multiplication by 100.

to cooperation on either policy in isolation. Hence, there is a notable *policy complementarity* where simultaneously subsidising knowledge creation (innovation) and knowledge diffusion (FDI) yields greater gains than the sum of the individual policies applied separately. Second, cooperative FDI subsidies disproportionately benefit the East.

FDI generates externalities distinct from those associated with innovation, thus a specific policy instrument to correct them can only give larger welfare gains. The model reveals the substantial quantitative impact of combining the two policy instruments—more than doubling the welfare gains compared to using the R&D subsidy alone. The R&D subsidy in the West is smaller and the FDI subsidy higher when the policy maker chooses both subsidies cooperatively than when it choses each of them in isolation. This suggests the presence of a powerful policy complementarity: promoting technology diffusion reduces the underinvestment in innovation by increasing the efficiency of the R&D technology in the East and therefore the need for policy support to directly stimulate innovation. The presence of policy complementarity also implies that the gains from jointly subsidising innovation and FDI, about 10% of long-run consumption, is substantially higher that the combined gain from subsidising these two activities separately, 6.8%.

The gains from FDI stem from two channels: internalising the strategic motive and benefiting from knowledge spillovers. While the latter is intuitive — since FDI facilitates knowledge flows — the former is less obvious. This result suggests that subsidising FDI, thus encouraging the relocation of production to the East, raises income in the East without significantly lowering income in the West. In effect, FDI subsidies create an "efficient" form of business stealing, where moving production abroad lowers production costs without excessively harming the West through creative destruction.[40] The West still benefits through knowledge spillovers, while the East reaps the rewards from both business stealing and spillovers, explaining its disproportionate gain.

Taking stock. The growth engine of the economy, knowledge spillovers, is the key driver of the gains from innovation policy cooperation, which benefits both regions. Reduced FDI costs amplify these gains, as FDI enhances the potential for knowledge diffusion, providing an additional rationale for cooperation. Furthermore, the complementarity between R&D and FDI subsidies highlights that jointly optimising incentives for innovation and diffusion yields significantly larger benefits compared to addressing them in isolation.

These findings suggest a critical policy implication: economic unions, such as the EU, could achieve substantial benefits by pooling resources from member states and allocating them centrally and asymmetrically across countries. This coordinated approach would maximise collective welfare, leveraging the unique strengths and needs of each region to foster innovation and growth.[41]

5 Robustness and extensions

Having presented our baseline findings, we now turn to perform robustness along two key dimensions. The first is with respect to the parameter space. The second is with regard to the model environment — we generalise our analysis to account for a third region.

5.1 Sensitivity and further insights

To better understand the main mechanisms in the model, we analyse the impact on our main results of small changes in key parameters. When possible, we perform the robustness increasing the benchmark value of each parameter by 10%. Table 5 shows the results.

The most relevant parameter for our results, unsurprisingly, is the one governing the strength of knowledge spillovers. Stronger spillovers, represented by an increase in ϕ, significantly amplify the gains from cooperation. To illustrate this, we compute the gains for a 10% and a 20% increase in ϕ above the baseline. These increases raise the baseline gains of 4.5% to 5.2% and 8.4%, respectively.

[40] Recall that when Western firms choose to relocate production abroad, they face a trade-off between lower production costs and a higher likelihood of being out-innovated due to knowledge diffusion.

[41] This aligns broadly with the objectives of the EU Framework Program, particularly the Structural and Investment Funds (see, e.g., European Commission, 2024)

The spillover parameter ϕ is calibrated to generate the observed average growth rate in multi-factor productivity of 0.66% for the set of countries included in our quantitative analysis. The steady-state growth rate analogue in our model is $n/((\sigma-1)(1-\phi))$. Using $\sigma = 3.2$ consistent with conservative empirical micro-estimates (e.g. Feenstra et al. (2018)) and the observed population growth of $n = 0.0044$, we obtain a baseline value of $\phi = 0.69$. The 10 and 20 percent increase in ϕ, considered in this robustness exercise, generate steady state growth rates of 0.82% and 1.1%, respectively – figures that remain conservative and align with the historical performance of the EU economy. Higher values of ϕ not only generate larger welfare gains but also intensify the incentive to subsidize the West. Notably, a 20% increase in ϕ above the baseline also leads to a significant reduction in the optimal R&D tax applied to the East.

Table 5 also suggests that when knowledge spillovers become less global, which happens for higher values of β, the gains from cooperation are smaller. More localised spillovers means weaker knowledge flows across borders. Raising β by 10% lowers the EU-wide benefit operating via intertemporal spillovers from 10.1% to 8.8%, while only lowering the strategic motive losses from 5.2% to 4.7%, culminating in total coordination gains of 3.7%, down from 4.5%. Moreover the optimal subsidy for the West drops from 31% to 29%.

Table 5: Robustness analysis

	Baseline			1.10ϕ			1.20ϕ			1.10β		
	s^W	s^E	s^M	s^W	s^E	s^M	s^W	s^E	s^M	s^W	s^E	s^M
Observed (s^W_o, s^E_o)	0.12	0.10	0.00	0.12	0.10	0.00	0.12	0.10	0.00	0.12	0.10	0.00
Harmonised (s^W_{co}, s^E_{co})	0.31	-0.99	0.00	0.45	-0.99	0.00	0.59	-0.79	0.00	0.29	-0.99	0.00
	W	E	EU	W	E	EU	W	E	EU	W	E	EU
Welfare gains	0.040	0.005	0.045	0.046	0.006	0.052	0.061	0.023	0.084	0.035	0.002	0.037
Strategic motive	-0.009	-0.044	-0.052	-0.025	-0.066	-0.091	-0.059	-0.096	-0.155	-0.007	-0.040	-0.047
Consumer surplus	-0.002	-0.002	-0.003	-0.001	-0.001	-0.002	0.000	0.000	0.000	-0.002	-0.002	-0.004
Intertemporal spillovers	0.050	0.050	0.101	0.073	0.073	0.145	0.120	0.120	0.240	0.044	0.044	0.088

	1.01τ			1.10σ			0.90α			1.10λ		
	s^W	s^E	s^M	s^W	s^E	s^M	s^W	s^E	s^M	s^W	s^E	s^M
Observed (s^W_o, s^E_o)	0.12	0.10	0.00	0.12	0.10	0.00	0.12	0.10	0.00	0.12	0.10	0.00
Harmonised (s^W_{co}, s^E_{co})	0.33	-0.97	0.00	0.33	-0.99	0.00	0.23	-0.97	0.00	0.33	-0.99	0.00
	W	E	EU	W	E	EU	W	E	EU	W	E	EU
Welfare gains	0.042	0.010	0.051	0.043	-0.004	0.039	0.044	0.005	0.049	0.045	-0.008	0.036
Strategic motive	-0.009	-0.041	-0.049	-0.007	-0.055	-0.062	-0.003	-0.043	-0.046	-0.008	-0.061	-0.069
Consumer surplus	-0.002	-0.002	-0.004	-0.002	-0.002	-0.003	-0.002	-0.002	-0.004	-0.001	-0.001	-0.003
Intertemporal spillovers	0.052	0.052	0.104	0.052	0.052	0.104	0.050	0.050	0.099	0.054	0.054	0.108

Notes. All calculations include transitional dynamics; welfare effects are in compensating variation (30) with $T = \infty$. The FDI subsidy is zero in all scenarios. Numbers are prior to multiplication by 100.

We find that increasing the iceberg trade cost τ from the free-trade baseline amplifies the benefits of cooperation. Higher trade barriers result in slightly increased Western cooperative subsidies and slightly reduced Eastern taxes, indicating that closed economies exacerbate market underinvestment in innovation. Trade openness, by enhancing competitive pressure and export market access, fosters innovation and growth, reducing the need for policymakers to address market failures caused by knowledge spillovers.[42]

We consider a value of the elasticity of substitution across varieties σ, which is 10% above its baseline value. Recall that the markup set by a given industry leader is given by $\sigma/(\sigma-1)$; a higher value of σ lowers this object. Profits shape the strength of the business stealing, or strategic motive, for cooperation. Lowering profits implies that there are less gains, or in our case, bigger losses, from the strategic motive for cooperation. As shown in the table.

To better understand the role of geography, we consider robustness on α — the degree of local decreasing returns in R&D. When taking a 10% lower value of α, meaning stronger decreasing returns, the cooperative policy shifts to place less emphasis on the West, with a lower optimal subsidy, in addition to more emphasis on the East, with a less extreme tax. Similar gains from intertempral spillovers to the baseline then come with this additional benefit from correcting the geographical distribution of R&D spending, yielding slightly higher EU gains.

Finally we conduct robustness on the innovation step size parameter λ, with a value 10% above its baseline. As one would expect, a higher value of this parameter strengthens the intertemporal spillovers channel, giving EU-wide effects of 10.8%, as opposed to 10.1% in the baseline. However, intensified competition for market share across the two countries leads to a significantly larger detraction from the EU gains through the strategic motive, with E losing 6%. This then culminates with the counter-intuitive result that the gains to cooperation can actually be lower when λ increases, highlighting the importance of considering policy exercises in an open economy setting.

5.2 A 3-region model

Our model abstracts from many complexities of real-world economies to emphasise the key forces driving incentives for policy cooperation. One notable simplification is the assumption that EU countries do not trade with the rest of the world, raising the question of how interactions with a third region might influence the main results. Additionally, our model focuses on cooperation between one advanced and one developing region, even though real-world technological competition for Western Europe is more likely to stem from the US or China rather than Eastern Europe.

To address these issues, we introduce a third region into the model. This extension serves two purposes. First, it examines how allowing for trade with a third region impacts the benefits of innovation policy cooperation within Europe. Second, it explores how cooperation with a more similar region affects Western Europe's incentives to cooperate. To isolate the key dynamics, we assume that this

[42] In a two-region Schumpeterian growth model where only one region sets its R&D subsidies optimally, Akcigit et al. (2018b) find that the optimal subsidy is declining in trade openness. Our result shows that a similar finding can be obtained when subsidies in both regions are set cooperatively.

third region, referred to as the Rest of the World (*RoW*), shares identical characteristics with the West, except that its firms do not engage in offshore production. This assumption allows us to focus on the strategic aspects of policy cooperation among similarly developed regions.[43]

The derivation of the extended model follows the same procedure as the baseline model and we relegate the details to Appendix B.3. In our quantitative exploration of the property of this extension, we consider a *RoW* region consisting of four economies, the USA, Canada, Japan and China, jointly accounting for 66% of the total world R&D expenditure in 2015.[44] The calibration details can be found in Appendix B.4. Armed with the calibrated model, we perform two quantitative exercises. First, we repeat the East-West cooperative R&D subsidy exercise as in the baseline model, to gain insight into the robustness of our baseline results. Secondly, we explore the gains from cooperation when a global planner sets the innovation subsidies in the three regions cooperatively. The results are reported in Table 6.

Table 6: Gains from cooperation: three-region model

	W-E cooperation				**W-E-RoW cooperation**			
	s^W	s^E	s^M	s^{RoW}	s^W	s^E	s^M	s^{RoW}
Observed (s_o^W, s_o^E, s_o^{RoW})	0.12	0.10	0.00	0.13	0.12	0.10	0.00	0.13
Harmonised ($s_{co}^W, s_{co}^E, s_{co}^{RoW}$)	0.58	-0.91	0.00	0.13	0.36	-0.68	0.00	-0.78
	W	E	EU	RoW	W	E	EU	RoW
Welfare gains	0.073	0.110	0.184	0.007	0.262	0.234	0.496	0.081
Strategic motive	-0.064	-0.027	-0.091	-0.131	0.002	-0.027	-0.025	-0.179
Consumer surplus	0.074	0.074	0.148	0.074	0.264	0.264	0.527	0.264
Intertemporal spillovers	0.064	0.064	0.127	0.064	-0.003	-0.003	-0.006	-0.003

Notes. All calculations take the transitional dynamics into account and the welfare effects are in compensating variation as (30) with $T = \infty$. Numbers are prior to multiplication by 100.

As in the baseline model, the optimal policy with W-E cooperation in the 3 region model remains to subsidise Western firms and tax those in the East. However, while the benchmark economy showed disproportionately higher gains for the West, the inclusion of a third region results in more balanced outcomes, shifting the gains such that the East in facts benefits more. In addition, although the *RoW* also gains from EU cooperation, the gains for the East and West are significantly larger. This is because the strategic motive penalises the *RoW* more heavily due to *trade diversion*, which in our model operates via business stealing. Cooperation boosts innovation within the EU, by subsidising the West, thereby boosting innovation and technology diffusion. Consequently, both W and E firms expand their leadership shares at the expense of *RoW*. This dynamic is evident in the decomposition of the sources of cooperation gains, where the costs of the strategic motive are smaller for the East and West compared to the RoW.[45]

[43] This approach also keeps the three-region model relatively simple and aligned with the main two-region EU framework.

[44] The three regions in our model account for 88% of the total world R&D expenditures in 2015 and 87% of the total world patent count.

[45] It is important to point out that these results are valid under the assumption that the RoW does not react (retaliate) to

Similarly to the baseline model, knowledge spillovers outweigh the strategic motive in driving the gains from cooperation. However, the consumer surplus channel now plays a more prominent role. This follows from the re-distribution of manufacturing activity from *RoW* over to the East through the activity of Western multinationals. Given that the manufacturing efficiency of Eastern firms, Western multinationals and firms from *RoW* are the same in our calibration, in addition to the wage being lower in the East than *RoW* ($w^E < w^R$), we observe a positive impact on the geographical component of the price index, $\bar{P}^j$ for $j = W, E, RoW$. As a result, households benefit from a reduction in the geographical component of the price index, enhancing welfare and reinforcing the consumer surplus channel's importance in the cooperative framework.

Finally, we give some discussion to cooperation across all three regions. The optimal policy of the global planner remains to subsidise the West and tax the East, but now also includes taxing the *RoW*. This reinforces key insight obtained in the baseline model, that it is globally beneficial to subsidise the region with the most efficient innovation technology. That is, since $\gamma^W > \gamma^K$ for $K = E, M, RoW$ in the calibration, and the West is the key source of cross-border spillovers via FDI, it is optimal to subsidise Western innovation while taxing innovation in the other regions. Another notable result is that the gains from global cooperation are significantly larger for the EU compared to the case of EU-only cooperation, highlighting the enhanced benefits of a broader collaborative framework.

Cooperation with the more advanced *RoW* yields substantially larger gains for Western Europe, compared to cooperation with the less advanced Eastern European region. This disparity arises because the *RoW* poses a greater competitive threat to Western firms; the lack of endogenous idea diffusion via FDI between the two regions shifts the source of cooperation benefits. Unlike *W*-*E* cooperation, where gains are largely driven by internalising knowledge spillovers, the benefits of *W*-*E*-*RoW* cooperation stem primarily from other mechanisms. Our decomposition of the gains highlights two key differences between the two cooperation scenarios. First, in the *W*-*E*-*RoW* case, Western Europe experiences smaller losses from the strategic channel, as aligning policies with *RoW* reduces harmful strategic policies. Second, the gains from the consumer surplus channel are larger, as broader cooperation reduces the quality-adjusted price index more significantly.

In summary, the inclusion of the *RoW* in cooperation agreements enables Western Europe to mitigate strategic disadvantages while reaping greater consumer benefits, demonstrating the value of engaging with similarly advanced and competitive regions. This underscores the importance of tailoring cooperation policies to the specific characteristics and competitive dynamics of the partner regions.

the changes in EU innovation policy.

6 Conclusion

Motivated by the institutional developments of the EU, particularly in fostering a unified innovation agenda, this paper provides a framework to analyse innovation policy cooperation among countries closely integrated via trade and FDI. We apply the framework to asses the gains from innovation policy cooperation in the European Union.

The analysis reveals that significant differences in innovation capabilities between the West (old member states) and the East (new member states) are central to the formulation of optimal policies. Western countries exhibit higher R&D efficiency and are a major source of knowledge spillovers via the technology transfer induced by FDI. These asymmetries, along with the congestion externalities in innovation and locally biased knowledge flows, underscore the complexity of designing policies in this challenging environment.

Our results indicate that a cooperative policy should involve substantial subsidies for Western innovation and innovation taxes for the East. This policy leverages the West's superior innovation efficiency and its critical role in cross-border knowledge dissemination through FDI. The results highlight substantial welfare gains from such coordination. However, these gains are unevenly distributed, favoring the West due to its stronger innovation base and expanded profits from intensified offshoring.

The primary driver of these gains is the internalization of knowledge spillovers. In an open economy, innovation subsidies in one region amplify innovation potential across borders, addressing underinvestment caused by the failure to account for cross-border spillover effects. Our findings also demonstrate the complementarity between innovation subsidies and FDI subsidies, emphasising that simultaneous support for knowledge creation and diffusion yields greater benefits than applying each policy independently.

Extending our baseline model to include a third region — the Rest of the World, encompassing the United States, Canada, Japan, and China — reveals that both cooperation at the EU level and global cooperation yield larger gains than when considering the EU as a closed economy. These findings provide broader insights into the ongoing global technology competition, primarily between the US and China but involving the EU, Japan and several other countries as well, suggesting that technological protectionism damages global prosperity, reducing innovation and productivity growth. Low barriers to international technology diffusion accelerate growth and function as a multiplier of the effects of local and global innovation policy.

While our framework is rich in its conceptual scope, it is still very stylised. The development of a large-scale, open-economy Schumpeterian growth model capable of incorporating multiple countries and their technological heterogeneity remains an open frontier in the literature. Schumpeterian models are particularly appropriate for policy analysis due to their nuanced treatment of the trade-offs between creative destruction and knowledge spillovers, which can lead to either underinvestment or overinvestment in innovation. Extending such models to encompass more detailed multinational production dynamics and a broader range of countries is an exciting and valuable direction for future research.

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Online Appendix

A Motivating facts

A.1 Innovation performance and policy in the EU

Figure A.1: Patent granted at the European Patent Office (% EU Total)

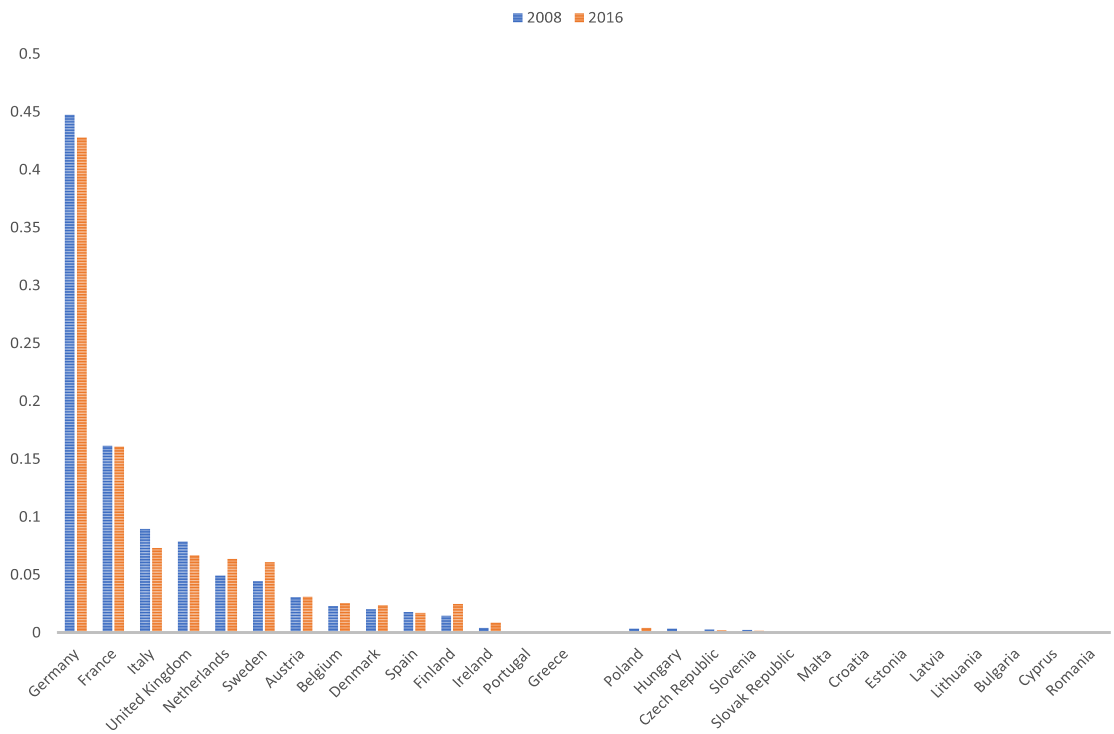
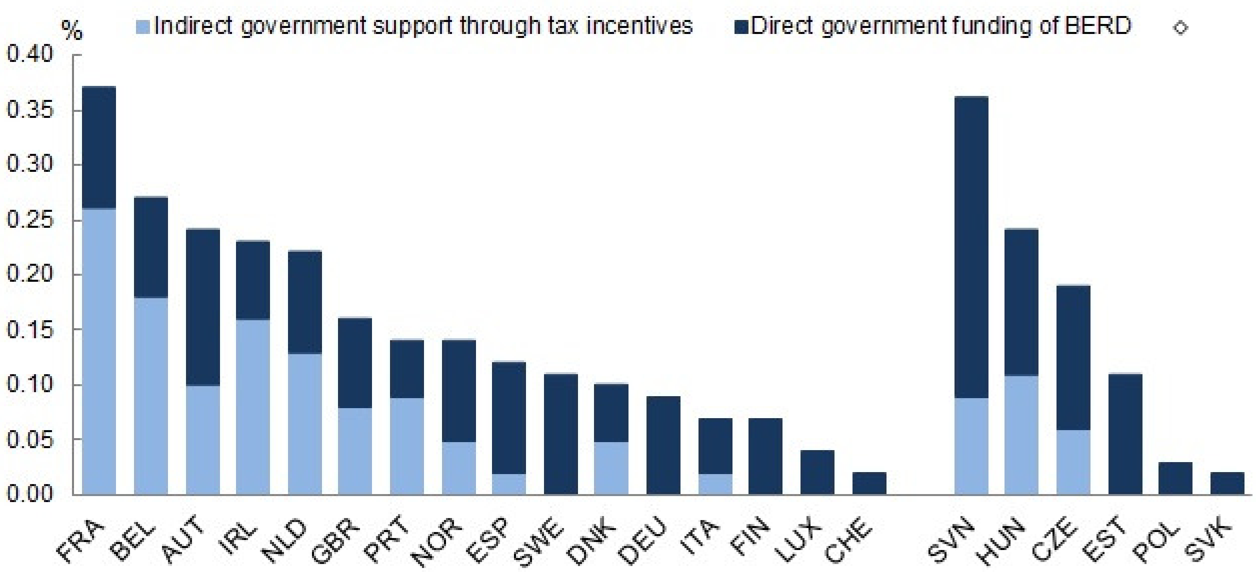


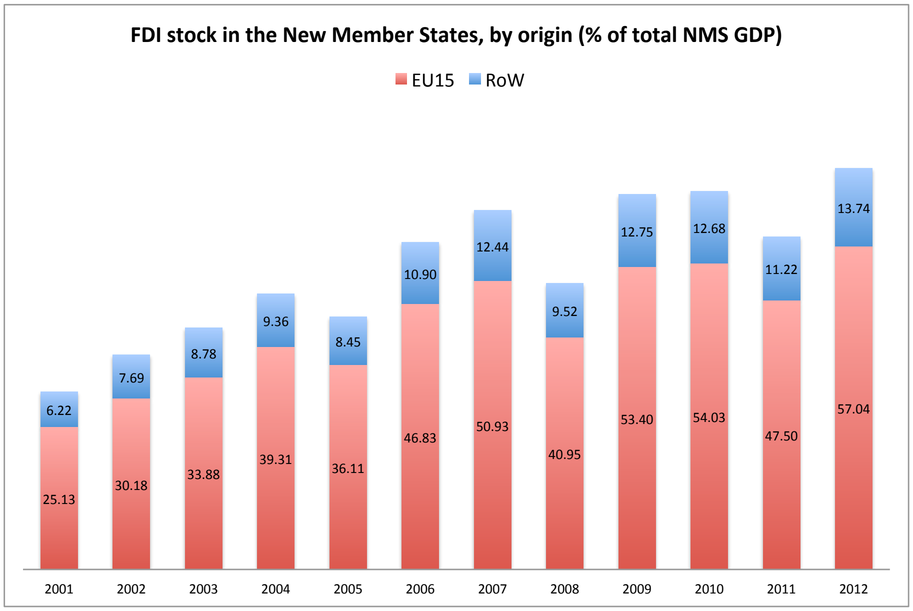
Figure A.2: Public support to innovation (2012)



Notes. Direct support includes grants, contracts, loans and subsidies, Indirect support includes tax allowances, credits, and accelerated depreciation of R&D capital expenditures. Source: OECD R&D Tax Incentives Indicators.

A.2 FDI and innovation

Figure A.3: West-East Foreign direct investment acceleration



Notes. Source: Eurostat.

Table A.1: Domestic firms reporting innovation and foreign firms by region-sector
Robustness

Dependent variable: Dummy variable for domestic firms reporting innovation				
Explanatory variable	Dummy	Share	Dummy	Share
	(1)	(2)	(3)	(4)
	Region-sector with > 30 obs		Region-sector with < 30 obs	
Foreign presence	0.217***	2.754**	0.025**	0.173**
	(0.046)	(1.099)	(0.012)	(0.069)
Observations	3,184	3,184	10,890	10,890
R-squared	0.116	0.116	0.181	0.181
	Nb obs as a control variable		Log(nb obs) as a control variable	
Foreign presence	0.036***	0.200***	0.041***	0.203***
	(0.012)	(0.063)	(0.012)	(0.063)
Observations	10,593	10,593	10,593	10,593
R-squared	0.208	0.208	0.208	0.208
	Private firms		State-owned firms	
Foreign presence	0.040***	0.210***	-0.115	-1.153
	(0.013)	(0.063)	(0.146)	(1.667)
Observations	10,474	10,474	83	83
R-squared	0.206	0.206	0.661	0.664
	Sales above median		Sales below median	
Foreign presence	0.050***	0.193**	0.030**	0.242**
	(0.018)	(0.076)	(0.013)	(0.113)
Observations	5,235	5,235	5,169	5,169
R-squared	0.223	0.222	0.217	0.218
	Exporters		Non-exporters	
Foreign presence	0.045**	0.199	0.036*	0.200**
	(0.019)	(0.133)	(0.018)	(0.091)
Observations	2,218	2,218	8,363	8,363
R-squared	0.245	0.244	0.205	0.205
	Importers		Non-importers	
Foreign presence	0.043*	0.200	0.031*	0.171**
	(0.025)	(0.129)	(0.016)	(0.073)
Observations	2,167	2,167	8,416	8,416
R-squared	0.242	0.241	0.200	0.200

Notes. All regressions include region, sector and year fixed effects. All regressions include the following firm-level control variables: firms' log of sales, and a set of dummy variables for state-owned enterprises, exporting firms, importing firms. Robust standard error clustered both at the region and at the sector level into brackets. *, **, *** significantly different from 0 at 1%, 5% and 10% level, respectively.

B Model derivations

B.1 Baseline model derivations

B.1.1 Equilibrium conditions

labour market clearing. labour demand in the West comes from production located in the West, ω^W, and R&D activities in all sectors. Workers in the East are employed in production activities by western multinationals in ω^M sectors and by eastern firms in sectors ω^E. labour demand for eastern workers comes also from western firms' adaptive R&D, targeting ω^W sectors for production transfer and from eastern firms' innovation in sectors where FDI has previously occurred (ω^M and ω^E).

Substituting (4) and (5) for p^W and p^{*W}, and (10) for $A^W(t)$, we derive the labour market clearing condition in the West as

$$\begin{aligned}
\ell^W &= \int_{\omega^W} a^W q(\omega,t) p^{W(-\sigma)} \frac{c^W \ell^W}{P^W(t)^{1-\sigma}} d\omega + \int_{\omega^W} \tau^W a^W q(\omega,t) p^{*W(-\sigma)} \frac{c^E(1-\ell^W)}{P^E(t)^{1-\sigma}} d\omega + \int_0^1 \frac{I^{W\frac{1}{1-\alpha}}}{A^W(t)L(t)} d\omega \\
&= \left(\frac{\sigma}{\sigma-1}\right)^{-\sigma} a^{W(1-\sigma)} \left(\frac{c^W \ell^W}{P^W(t)^{1-\sigma}} + \frac{c^E(1-\ell^W)}{P^E(t)^{1-\sigma}} \tau^{W(1-\sigma)}\right) \int_{\omega^W} q(\omega,t) d\omega + \frac{I^{W\frac{1}{1-\alpha}}}{\gamma^W} \frac{\int_0^1 q(\omega,t) d\omega}{\hat{Q}^W(t)^\phi L(t)} \\
&= \left(\frac{\sigma}{\sigma-1}\right)^{-\sigma} a^{W(1-\sigma)} q^W \left(\frac{c^W \ell^W}{\bar{P}^W(t)^{1-\sigma}} + \frac{c^E(1-\ell^W)}{\bar{P}^E(t)^{1-\sigma}} \tau^{W(1-\sigma)}\right) + \frac{I^{W\frac{1}{1-\alpha}}}{\gamma^W} \frac{Q(t)}{\hat{Q}^W(t)^\phi L(t)}.
\end{aligned} \tag{B.1}$$

where $\ell^W = L^W(t)/(L^W(t)+L^E(t)) = L^W(t)/L(t)$ is the share of total EU labour force in region W, $\bar{P}^{K(1-\sigma)} = P^K(t)^{1-\sigma} Q(t)^{-1}$, $Q(t) = \int_0^1 q(\omega,t) d\omega$, $Q^W(t) = \int_{\omega^W} q(\omega,t) d\omega$ and $q^W = \frac{Q^W(t)}{Q(t)}$. In the East, with $Q^{E(t)} = \int_{\omega^E} q(\omega,t) d\omega$ and $q^E = \frac{Q^E(t)}{Q(t)}$, we obtain

$$\begin{aligned}
1-\ell^W &= \int_{\omega^E} \tau^E a^E q(\omega,t) p^{*E(-\sigma)} \frac{c^W l^W}{P^W(t)^{1-\sigma}} d\omega + \int_{\omega^E} a^E q(\omega,t) p^{E(-\sigma)} \frac{c^E(1-\ell^W)}{P^E(t)^{1-\sigma}} d\omega \\
&+ \int_{\omega^M} \tau^E a^M q(\omega,t) p^{*M(-\sigma)} \frac{c^W l^W}{P^W(t)^{1-\sigma}} d\omega + \int_{\omega^M} a^M q(\omega,t) p^{M(-\sigma)} \frac{c^E(1-\ell^W)}{P^E(t)^{1-\sigma}} d\omega \\
&+ \int_{\omega^E+\omega^M} \frac{I^{E\frac{1}{1-\alpha}}}{A^E(t)L(t)} d\omega + \int_{\omega^W} \frac{I^{M\frac{1}{1-\alpha}}}{A^M(t)L(t)} d\omega \\
&= \left(\frac{\sigma}{\sigma-1}\right)^{-\sigma} w^{E(-\sigma)} a^{E(1-\sigma)} \left(\frac{c^W l^W}{P^{W(1-\sigma)}} \tau^{E(1-\sigma)} + \frac{c^E(1-l^W)}{P^{E(1-\sigma)}}\right) \int_{\omega^E} q(\omega,t) d\omega \\
&+ \left(\frac{\sigma}{\sigma-1}\right)^{-\sigma} w^{E(-\sigma)} a^{M(1-\sigma)} \left(\frac{c^W l^W}{P^{W(1-\sigma)}} \tau^{E(1-\sigma)} + \frac{c^E(1-l^W)}{P^{E(1-\sigma)}}\right) \int_{\omega^M} q(\omega,t) d\omega \\
&+ \frac{I^{E\frac{1}{1-\alpha}}}{\gamma^E} \frac{\int_{\omega^E+\omega^M} q(\omega,t) d\omega}{\hat{Q}^E(t)^\phi L(t)} + \frac{I^{M\frac{1}{1-\alpha}}}{\gamma^M} \frac{\int_{\omega^W} q(\omega,t) d\omega}{\hat{Q}^W(t)^\phi L(t)} \\
&= \left(\frac{\sigma}{\sigma-1}\right)^{-\sigma} w^{E(-\sigma)} \left(a^{E(1-\sigma)} q^E + a^{M(1-\sigma)} q^M\right) \left(\frac{c^W \ell^W}{\bar{P}^{W(1-\sigma)}} \tau^{E(1-\sigma)} + \frac{c^E(1-\ell^W)}{\bar{P}^{E(1-\sigma)}}\right) \\
&+ \frac{I^{E\frac{1}{1-\alpha}}}{\gamma^E} \frac{Q^{(M+E)}(t)}{\hat{Q}^E(t)^\phi L(t)} + \frac{I^{M\frac{1}{1-\alpha}}}{\gamma^M} \frac{Q^W(t)}{\hat{Q}^W(t)^\phi L(t)}.
\end{aligned} \tag{B.2}$$

Quality aggregates. The average quality index $Q(t)$ equals the sum of the sectoral quality aggretates

$$\begin{aligned} Q(t) &= \int_{\omega^W} q(\omega,t)d\omega + \int_{\omega^E} q(\omega,t)d\omega + \int_{\omega^M} q(\omega,t)d\omega \\ &= Q^W(t) + Q^E(t) + Q^M(t), \end{aligned} \tag{B.3}$$

which gives the condition $1 = q^W(t) + q^E(t) + q^M(t)$. The quality aggregate in the West changes due to quality upgrades of Western products, leadership takeover from the Eastern incumbent innovators and the multinationals and due to the transfer of production to subsidiary firms in the East. The following expression describes the evolution of Q^W, as a result of innovation and production transfers

$$\begin{aligned} \dot{Q}^W(t) &= \int_{\omega^W} [\lambda^{(\sigma-1)(j(\omega,t)+1)} - \lambda^{(\sigma-1)j(\omega,t)}] I^W d\omega + \int_{\omega^E} \lambda^{(\sigma-1)(j(\omega,t)+1)} I^W d\omega \\ &+ \int_{\omega^M} \lambda^{(\sigma-1)(j(\omega,t)+1)} I^W d\omega - \int_{\omega^W} \lambda^{(\sigma-1)j(\omega,t)} I^M d\omega, \\ &= (\lambda^{\sigma-1} - 1) I^W Q^W(t) + \lambda^{\sigma-1} I^W (Q^E(t) + Q^M(t)) - I^M Q^W(t). \end{aligned} \tag{B.4}$$

Similarly, for the aggregate quality of the eastern innovators and multinationals' production

$$\begin{aligned} \dot{Q}^E(t) &= \int_{\omega^E} [\lambda^{(\sigma-1)(j(\omega,t)+1)} - \lambda^{(\sigma-1)j(\omega,t)}] I^E d\omega + \int_{\omega^M} \lambda^{(\sigma-1)(j(\omega,t)+1)} I^E d\omega - \int_{\omega^E} \lambda^{(\sigma-1)j(\omega,t)} I^W d\omega \\ &= (\lambda^{\sigma-1} - 1) I^E Q^E(t) + \lambda^{\sigma-1} I^E Q^M(t) - I^W Q^E(t), \end{aligned} \tag{B.5}$$

$$\begin{aligned} \dot{Q}^M(t) &= \int_{\omega^W} \lambda^{(\sigma-1)j(\omega,t)} I^M d\omega - \int_{\omega^M} \lambda^{(\sigma-1)j(\omega,t)} I^W d\omega - \int_{\omega^M} \lambda^{(\sigma-1)j(\omega,t)} I^E d\omega \\ &= I^M Q^W(t) - (I^W + I^E) Q^M(t) \end{aligned} \tag{B.6}$$

The average product quality of all the production in the East is given by $Q^{EM}(t) = Q^E(t) + Q^M(t)$ and it evolves according to

$$\begin{aligned} \dot{Q}^{EM}(t) &= \dot{Q}^E(t) + \dot{Q}^M(t) \\ &= (\lambda^{\sigma-1} - 1) I^E Q^{EM} + I^M Q^W(t) - I^W (Q^E(t) + Q^M(t)). \end{aligned}$$

Finally, adding (B.4), (B.5), (B.6) and dividing by $Q(t)$ we obtain the equilibrium growth of the quality aggregate $Q(t)$ and its components which determines the growth rate of the the two regions given by equation (19).

Competitive equilibrium. The competitive equilibrium for this economy is thus characterised by the following. The free entry and arbitrage conditions (13) for the West, the East and multinationals incumbent firms, the firm value for both countries (12), the aggregate assets for both countries (22), the laws of motion for quality (B.3), (B.4), (B.5), (B.6) and (19), the market clearing conditions (B.1), (B.2), the Euler equation (3), and one of aggregate budget constrains (21), as trade balanced implies that once one of them is satisfied the other is as well. These 17 equilibrium equations determine 17 endogenous variables, c^W, c^E, I^W, I^E, I^M, w^E, v^W, v^E, v^M, $\mathscr{A}^W$, $\mathscr{A}^E$, Q^W, Q^E, Q^M, Q, g and r.

B.1.2 Balanced growth path

Balanced growth free entry conditions. As noted in the benchmark model description for the BGP, with constant wages and innovation arrival rates, $\dot{v^k}(t)/v^k(t) = -\dot{A}^K(t)/A^K(t) = -\phi g$, for $K = W, E, M$. Substituting for profits and the marginal product of research (MRI) in (13), we determine the BGP free entry conditions in three different types of sectors (firms) as

$$\frac{(1-s^W)}{\gamma^W}(q^W)^{-\beta\phi}x = \frac{\frac{a^{W(1-\sigma)}\sigma^{-\sigma}}{(\sigma-1)^{(1-\sigma)}}\left(\frac{c^W\ell^W(t)}{(\bar{P}^W)^{(1-\sigma)}} + \frac{c^E(1-\ell^W)}{(\bar{P}^E)^{(1-\sigma)}}\tau^{W(1-\sigma)}\right)}{\rho + I^W + \phi g} I^{W\frac{\alpha}{\alpha-1}} \quad \text{for } \omega \in \omega^W, \tag{B.7}$$

$$\frac{(1-s^E)w^E}{\gamma^E}(q^E)^{-\beta\phi}x = \frac{\frac{\sigma^{-\sigma}}{(\sigma-1)^{(1-\sigma)}}a^{E(1-\sigma)}w^{E(1-\sigma)}\left(\frac{c^W\ell^W}{(\bar{P}^W)^{(1-\sigma)}}\tau^{E(1-\sigma)} + \frac{c^E(1-\ell^W)}{(\bar{P}^E)^{(1-\sigma)}}\right)}{\rho + I^W + I^E + \phi g} I^{E\frac{\alpha}{\alpha-1}} \quad \text{for } \omega \in \omega^E, \tag{B.8}$$

$$\begin{aligned}\frac{(1-s^M)w^E}{\gamma^M}(q^W)^{-\beta\phi}x = \frac{\sigma^{-\sigma}}{(\sigma-1)^{(1-\sigma)}}&\left[\frac{a^{M(1-\sigma)}w^{E(1-\sigma)}}{\rho + I^W + I^E + \phi g}\left(\frac{c^W\ell^W(t)}{(\bar{P}^W)^{(1-\sigma)}}\tau^{E(1-\sigma)} + \frac{c^E(1-\ell^W)}{(\bar{P}^E)^{(1-\sigma)}}\right)\right.\\ &\left.-\frac{a^{W(1-\sigma)}}{\rho + I^W + \phi g}\left(\frac{c^W\ell^W}{(\bar{P}^W)^{(1-\sigma)}} + \frac{c^E(1-\ell^W)}{(\bar{P}^E)^{(1-\sigma)}}\tau^{W(1-\sigma)}\right)\right] I^{M\frac{\alpha}{\alpha-1}} \quad \text{for } \omega \in \omega^M,\end{aligned} \tag{B.9}$$

where $x = Q(t)^{1-\phi}/L(t)$ is stationary.

Quality aggregates on the BGP. Invariance of sectoral composition in any steady-state equilibrium requires that the growth rates of the average quality Q and its components (quality aggregates) must be constant and equal to each other. Equating the growth of quality aggregates in the West and in the East, $\frac{\dot{Q}^W(t)}{Q^W(t)} = \frac{\dot{Q}^{EM}(t)}{Q^{EM}(t)}$, to satisfy the invariance of sectoral composition, we obtain

$$\lambda^{\sigma-1}\frac{I^W}{q^W} = \frac{I^M}{q^M + q^E} + (\lambda^{\sigma-1} - 1)I^E. \tag{B.10}$$

Similarly, the growth rate of quality aggregates in sectors with Eastern leaders and those in sectors with multinational leaders have to be the same in a steady-state equilibrium, $\frac{\dot{Q}^E(t)}{Q^E(t)} = \frac{\dot{Q}^M(t)}{Q^M(t)}$, which yields the condition

$$\frac{q^W(t)}{q^M(t) + q^E(t)} = \lambda^{\sigma-1}\frac{I^E}{I^M}\frac{q^M(t)}{q^E(t)}. \tag{B.11}$$

Sectoral composition. In steady state the shares of the three types of sectors in the economy must be constant. Hence, the outflows and the inflows into each type of sectors have to be equalised. In the West, $\omega^W I^M = (\omega^M + \omega^E)I^W$, where the right hand side is the flow out of sectors with western leadership and the left hand side is the flow into those sectors. Rearranging we obtain $\omega^W = \frac{I^W}{I^M + I^W}$. The condition for the sectors with eastern leadership is given by $\omega^E I^W = \omega^M I^E$, which, using $\omega^W + \omega^M + \omega^E = 1$, yields $\omega^E = \frac{I^M}{I^M + I^W}\frac{I^E}{I^E + I^W}$. Finally, the share of sectors with production by multinationals is given by

$\omega^M = \frac{I^M}{I^M+I^W}\frac{I^W}{I^E+I^W}$.

Equations (13) for the three types of sectors, (B.10)-(B.11), (19) and (B.1)-(B.2) define a set of BGP conditions for endogenous variables c^W, c^E, I^W, I^E, I^M, w^E, q^W, q^M and q^E. To close the model, we derive the expressions for per capita assets and expenditures below.

Assets. Assets per capita in each region given by (22) are derived as per capita value of all incumbent firms holding the existing patents. With constant wages and innovation arrival rates, and taking into account that $q(\omega,t)$ is fixed during an R&D race, it follows from the free entry condition (11) that the BGP growth in the firm value is found as $\dot{v^K}(t)/v^K(t) = -\dot{A}^K(t)/A^K(t) = -\phi g$, for $K = W,E$, with g as the growth rate of the average quality $Q(t)$ and each of its components, and thus also of the composite spillover $\hat{Q}^K(t)$.

Denoting the time of a patent's introduction in the market by a (with $t-a$ being the age of the patent at time t), and using the free entry condition (11) to express the value of the firms in terms of the innovation cost, we can derive the BGP per capita assets in the West and East in (22) as

$$
\begin{aligned}
\mathscr{A}^W(t) &= \int\limits_{\omega^W+\omega^M} \frac{v^W(\omega,t)}{L^W(t)}d\omega + \int\limits_{\omega^M} \frac{v^M(\omega,t)-v^W(\omega,t)}{L^W(t)}d\omega \\
&= \int\limits_{\omega^W+\omega^M} \frac{v^W(\omega,a)e^{-\phi g(t-a)}}{L^W(t)}d\omega + \int\limits_{\omega^M} \frac{(v^M(\omega,a)-v^W(\omega,a))e^{-\phi g(t-a)}}{L^W(t)}d\omega \\
&= \int\limits_{\omega^W}(1-s^W)\frac{I^{W\frac{\alpha}{1-\alpha}}}{\gamma^W L^W(t)}\frac{q(\omega,a)}{\hat{Q}^W(a)^\phi}e^{-\phi g(t-a)}d\omega + \int\limits_{\omega^M}(1-s^M)w^E\frac{I^{M\frac{\alpha}{1-\alpha}}}{\gamma^M L^W(t)}\frac{q(\omega,a)}{\hat{Q}^W(a)^\phi}e^{-\phi g(t-a)}d\omega \\
&= (1-s^W)\frac{I^{W\frac{\alpha}{1-\alpha}}}{\gamma^W L^W(t)}\frac{\int_{\omega^W} q(\omega,a)}{(\hat{Q}^W(t)e^{-g(t-a)})^\phi}e^{-\phi g(t-a)}d\omega + (1-s^M)w^E\frac{I^{M\frac{\alpha}{1-\alpha}}}{\gamma^M L^W(t)}\frac{\int_{\omega^M} q(\omega,a)}{(\hat{Q}^W(t)e^{-g(t-a)})^\phi}e^{-\phi g(t-a)}d\omega \\
&= (1-s^W)\frac{I^{W\frac{\alpha}{1-\alpha}}}{\gamma^W}\frac{Q^W(t)}{\hat{Q}^W(t)^\phi L^W(t)} + (1-s^M)w^E\frac{I^{M\frac{\alpha}{1-\alpha}}}{\gamma^M}\frac{Q^M(t)}{\hat{Q}^W(t)^\phi L^W(t)} \\
&= (1-s^W)\frac{I^{W\frac{\alpha}{1-\alpha}}}{\gamma^W}\frac{(q^W)^{(1-\beta\phi)}x}{\ell^W} + (1-s^M)w^E\frac{I^{M\frac{\alpha}{1-\alpha}}}{\gamma^M}\frac{q^M(q^W)^{(-\beta\phi)}x}{\ell^W} \qquad \text{(B.12)}
\end{aligned}
$$

and

$$
\begin{aligned}
\mathscr{A}^E(t) &= \int\limits_{\omega^E}\frac{v^E(\omega,t)}{L^E(t)}d\omega = \int\limits_{\omega^E}\frac{v^E(\omega,a)e^{-\phi g(t-a)}}{L^E(t)}d\omega = \int\limits_{\omega^E}(1-s^E)w^E\frac{I^{E\frac{\alpha}{1-\alpha}}}{\gamma^E L^E(t)}\frac{q(\omega,a)}{\hat{Q}^E(a)^\phi}e^{-\phi g(t-a)}d\omega \\
&= (1-s^E)w^E\frac{I^{E\frac{\alpha}{1-\alpha}}}{\gamma^E L^E(t)}\frac{\int_{\omega^E} q(\omega,a)}{(\hat{Q}^E(t)e^{-g(t-a)})^\phi}e^{-\phi g(t-a)}d\omega = (1-s^E)w^E I^{E\frac{\alpha}{1-\alpha}}\frac{1}{\gamma^E}\frac{Q^E(t)}{\hat{Q}^E(t)^\phi L^E(t)} \\
&= (1-s^E)w^E I^{E\frac{\alpha}{1-\alpha}}\frac{1}{\gamma^E}\frac{(q^E)^{1-\beta\phi}x}{\ell^E}, \qquad \text{(B.13)}
\end{aligned}
$$

where $\ell^E = 1-\ell^W$.

Expenditures. Noting from the assets expressions above that assets per capita remain constant on the BGP when $g = \frac{n}{1-\phi}$, it follows that (21) can be written as $c^K(t) = w^K(t) + (\rho - n)\mathscr{A}^K - T^K(t)$. Substituting the two assets conditions above and the expressions for taxes per capita used to finance the subsidies

$$
\begin{aligned}
T^W &= \frac{s^W}{L^W(t)} \int_0^1 L_R^W(\omega,t)d\omega = s^W I^{W\frac{1}{1-\alpha}} \frac{1}{\gamma^W} \frac{Q(t)}{\hat{Q}^W(t)^\phi L^W(t)} = s^W I^{W\frac{1}{1-\alpha}} \frac{1}{\gamma^W} \frac{(q^W)^{-\beta\phi}}{\ell^W} x, \\
T^E &= \frac{s^E}{L^E(t)} \int_{\omega^{M+E}} L_R^E(\omega,t)d\omega + \frac{s^M}{L^E(t)} \int_{\omega^W} L_R^M(\omega,t)d\omega \\
&= s^E w^E \frac{I^{E\frac{1}{1-\alpha}}}{\gamma^E} \frac{Q^{M+E}(t)}{\hat{Q}^E(t)^\phi L^E(t)} + s^M w^E \frac{I^{M\frac{1}{1-\alpha}}}{\gamma^M} \frac{Q^W(t)}{\hat{Q}^E(t)^\phi L^E(t)} \\
&= s^E w^E \frac{I^{E\frac{1}{1-\alpha}}}{\gamma^E} \frac{1}{\ell^E} \left(q^M (q^E)^{-\beta\phi} + (q^E)^{1-\beta\phi} \right) x + s^M w^E \frac{I^{M\frac{1}{1-\alpha}}}{\gamma^M} \frac{1}{\ell^E} q^W (q^E)^{-\beta\phi} x
\end{aligned}
$$

for the West and the East, respectively, into the expressions for BGP per-capita consumer expenditure, we obtain the steady-state per capita consumption as

$$
\begin{aligned}
c^W &= 1 + (\rho - n)\mathscr{A}^W - T^W \\
&= 1 + (\rho - n) \left[(1 - s^W) \frac{I^{W\frac{\alpha}{1-\alpha}}}{\gamma^W} \frac{(q^W)^{(1-\beta\phi)} x}{\ell^W} + (1 - s^M) w^E \frac{I^{M\frac{\alpha}{1-\alpha}}}{\gamma^M} \frac{(q^M)^{(1-\beta\phi)} x}{\ell^W} \right] \\
&- s^W I^{W\frac{1}{1-\alpha}} \frac{1}{\gamma^W} \frac{(q^W)^{(-\beta\phi)}}{\ell^W} x,
\end{aligned}
\tag{B.14}
$$

for the West. Similarly, for the East

$$
\begin{aligned}
c^E &= w^E + (\rho - n)\mathscr{A}^E - T^E \\
&= w^E \left[1 + (\rho - n) \left((1 - s^E) I^{E\frac{\alpha}{1-\alpha}} \frac{1}{\gamma^E} \frac{q^E(t)^{1-\beta\phi} x}{\ell^E} \right) \right. \\
&- \left. s^E \frac{I^{E\frac{1}{1-\alpha}}}{\gamma^E} \frac{1}{\ell^E} \left(q^M (q^E)^{-\beta\phi} + (q^E)^{1-\beta\phi} \right) x + s^M \frac{I^{M\frac{1}{1-\alpha}}}{\gamma^M} \frac{1}{\ell^E} q^W (q^E)^{-\beta\phi} x \right]
\end{aligned}
\tag{B.15}
$$

Balanced growth equilibrium. The balanced growth path is then characterised by the following. The free entry and arbitrage conditions (13) for the West and the East, the quality shares (B.10) and (B.11) plus $q^W + q^M = q^E = 1$, the growth equation $g = n/(1-\pi)$ together with (19), the market clearing conditions (B.1), (B.2), one of the aggregate budget constraints (B.15)-(B.15), as trade balanced implies that once one of them is satisfied the other is as well, and the Euler equation (3). These twelve equilibrium conditions determine twelve endogenous variables, c^W, c^E, I^W, I^E, I^M, w^E, q^W, q^E, q^M, r,

g and x.

B.2 External effects in simplified model

Closed economy economy. We derive the equilibrium innovation rate for the simple closed economy version. We use a simple linear R&D technology, assuming $\alpha = 0$ and $A(\omega, t) = A$ constant. This is the same specification used in Impullitti (2010). Steady state equilibrium consumption and innovation are given by the expenditure equation and by the free entry condition:

$$c = 1 + c\frac{\lambda - 1}{\lambda} - \frac{I}{A}$$
$$\frac{c\frac{\lambda-1}{\lambda}}{I + \rho - n}A = 1.$$

Solving the system we obtain equilibrium I and c.

Open economy. Following the same procedure as in the closed economy simple model we derive the business stealing effect. The impact of the external innovation on Western consumption is

$$\frac{dc^W}{d\Phi} = \left(\frac{dc^W}{d\Phi} + \frac{dc^E}{d\Phi}\right)\frac{\lambda - 1}{\lambda}\hat{\omega}$$

where

$$\frac{dc^E}{d\Phi} = \left(\frac{dc^W}{d\Phi} + \frac{dc^E}{d\Phi}\right)\frac{\lambda - 1}{\lambda}(1 - \hat{\omega}) - (c^W + c^E)\frac{\lambda - 1}{\lambda}\frac{d\hat{\omega}}{d\Phi}.$$

Since the successful external innovation steals the profits of an Eastern firm but these profits are not given to a Western firm we have included the impact on profits only for the latter, which embeds the term $d\hat{\omega}/d\Phi$, the change in the leadership share produced by the external innovation. Along the balanced growth path $\hat{\omega} = I^W/(I^W + I^E)$. Since the innovation by the external agent does not feature here, in order to compute its impact on $\hat{\omega}$ we take $d\hat{\omega}/d\Phi = d\hat{\omega}/dI^W = 1 - \hat{\omega}$. Summing the above equations and multiplying by the probability that no other innovation occurs between s and t we get

$$\frac{dc^W}{d\Phi} = -(c^W + c^E)\frac{(\lambda - 1)^2}{\lambda}\hat{\omega}(1 - \hat{\omega})e^{-(I^W + I^E)(s-t)}.$$

Using this into the business stealing component of the change in utility

$$BSE^W_{open} = \int_t^{\infty} e^{-(\rho - n)(s-t)}\frac{1}{c^W}\frac{dc^W}{d\Phi}dt = \left(\frac{\lambda - 1}{I^W + I^E + \rho - n}\right)\frac{\lambda - 1}{\lambda}\hat{\omega}(1 - \hat{\omega})\left(1 + \frac{c^E}{c^W}\right)$$

Under the symmetric countries assumption we have $I^W + I^E = 2I$, $c^W = c^E$ and $\bar{\omega} = 1/2$, we obtain (29).

B.3 Three-region model

Trade between the three regions is costly. An iceberg trade cost $\tau^{KJ} > 1$ implies that for one unit of any good to arrive from producer in location K to the export market J, τ^{KJ} units of good need to be shipped. With the assumption of costly participation, the leader charges the monopoly price in the domestic market

$$p^K(\omega,t) = \frac{\sigma}{\sigma-1} a^K w^K(t), \tag{B.16}$$

and the export monopoly price, denoted by $*$, for sales in the other regions

$$p^{*K}(\omega,t) = \frac{\sigma}{\sigma-1} a^K w^K(t) \tau^{KJ}. \tag{B.17}$$

Similarly, the domestic and export prices of a multinational are given by, $p^M(\omega,t) = \frac{\sigma}{\sigma-1} a^M w^E(t)$ and $p^{*M}(\omega,t) = \frac{\sigma}{\sigma-1} a^M w^E(t) \tau^{MJ}$, respectively, where we assume that $\tau^{ME} = 1$ as the multinationals are only located in the East. This leads to the expression for the total (domestic and export) monopoly profits of global quality leaders located in their respective regions, and of multinationals as

$$\begin{aligned}
\pi^K(\omega,t) &= \frac{1}{\sigma}\left(\frac{\sigma}{\sigma-1}\right)^{1-\sigma} (a^K w^K(t))^{1-\sigma} q(\omega,t) \left(\frac{c^K(t)L^K(t)}{P^K(t)^{1-\sigma}} + \sum_J \frac{c^J(t)L^J(t)}{P^J(t)^{1-\sigma}} (\tau^{KJ})^{1-\sigma} \right), \\
\pi^M(\omega,t) &= \frac{1}{\sigma}\left(\frac{\sigma}{\sigma-1}\right)^{1-\sigma} (a^M w^E(t))^{1-\sigma} q(\omega,t) \sum_J \frac{c^J(t)L^J(t)}{P^J(t)^{1-\sigma}} (\tau^{MJ})^{1-\sigma}.
\end{aligned} \tag{B.18}$$

with $K,J = W,E,RoW$, $K \neq J$. We again choose the western wage to be the numeraire of our economy, $w^W = 1$.

The innovation technology in the RoW is the same as (9) with the local bias for spillovers. As in the West, firms in RoW conduct innovation in all sectors of the economy, with the productivity A^{RoW}. Formally,

$$A^{RoW}(\omega,t) = \gamma^{RoW} \left(\frac{q(\omega,t)}{\hat{Q}^{RoW}(t)^{\phi}} \right)^{-1} \quad \text{for all } \omega \in \omega^{RoW}. \tag{B.19}$$

where $\hat{Q}^{RoW}(t) = Q^{RoW}(t)^{\beta^{RoW}} Q(t)^{(1-\beta^{RoW})}$ with $1/2 < \beta^{RoW} < 1$, and $Q^{RoW} = \int_{\omega^{RoW}} q(\omega,t) d\omega$ is the average quality of sectors with RoW leader producing in its region.

B.3.1 Equilibrium conditions

Free entry in innovation. As in the benchmark model, free entry pins down equilibrium innovation and FDI choice. In order to highlight the differences with the baseline model, here we report the free entry conditions, droping the sector and time subscripts(ω, t):

$$
\begin{aligned}
1-s^W &= \frac{\pi^W(1)}{r^W + I^W + I^{RoW} - \frac{\dot{v}^W}{v^W}} MPR(I^W) && \text{for } \omega \in \omega^W, \\
(1-s^E)w^E &= \frac{\pi^E(w^E)}{r^E + I^W + I^E + I^{RoW} - \frac{\dot{v}^E}{v^E}} MPR(I^E) && \text{for } \omega \in \omega^E, \\
(1-s^{RoW})w^{RoW} &= \frac{\pi^{RoW}(w^{RoW})}{r^{RoW} + I^W + I^{RoW} - \frac{\dot{v}^{RoW}}{v^{RoW}}} MPR(I^{RoW}) && \text{for } \omega \in \omega^{RoW}, \\
(1-s^M)w^E &= \left(\frac{\pi^M(w^E)}{r^E + I^W + I^E + I^{RoW} - \frac{\dot{v}^M}{v^M}} - \frac{\pi^W(1)}{r^W + I^W + I^{RoW} - \frac{\dot{v}^W}{v^W}} \right) MPR(I^M) && \text{for } \omega \in \omega^M,
\end{aligned}
\tag{B.20}
$$

where $MPR^K(\omega) = A^K(\omega,t)\left(I^K(\omega,t)\right)^{\frac{\alpha}{\alpha-1}}$, $K \in \{W, E, Row\}$, is the marginal productivity of innovative research for country K in sector ω, and $MPR^M(\omega) = A^M(\omega,t)\left(I^M(\omega,t)\right)^{\frac{\alpha}{\alpha-1}}$ is the marginal productivity of adaptive research resulting in the FDI. The government in the West subsidises both innovative R&D at the rate s^W and the adaptive research (FDI) needed to transfer technology abroad at a potentially different rate s^M, while the governements of the East and the RoW subsidise their home innovation at the respective rates, s^E and s^{RoW}. With the RoW now participating in the innovation race, the rate of creative distruction discounting the profits in any sector is augmented by I^{RoW}. At the same time, as the RoW conducts R&D in all sectors and imposes an additional business stealing threat to both the West and the East, the motives for subsidising EU innovation and FDI as the vehicle of within-EU knowledge spillover are strengthened.

labour market clearing. labour demand in the West and the RoW comes from production located in the West and the RoW, ω^W and ω^{RoW}, respectively, and R&D activities in all sectors. Workers in the East are employed in production in ω^M and ω^E sectors, as well as in the western firms' adaptive R&D and eastern firms' innovation in sectors where FDI has previously occurred. The labour market conditions in the West are derived as

$$
\begin{aligned}
\ell^W &= \left(\frac{\sigma}{\sigma-1}\right)^{-\sigma} a^{W(1-\sigma)} q^W \left(\frac{c^W \ell^W}{\bar{P}^{W(1-\sigma)}} + \frac{c^E \ell^E}{\bar{P}^{E(1-\sigma)}} \tau^{WE(1-\sigma)} + \frac{c^{RoW}(1-\ell^W-\ell^E)}{\bar{P}^{RoW(1-\sigma)}} \tau^{WRoW(1-\sigma)} \right) \\
&+ \frac{I^{W\frac{1}{1-\alpha}}}{\gamma^W} \frac{Q(t)}{\hat{Q}^W(t)^\phi L(t)},
\end{aligned}
\tag{B.21}
$$

Similarly, in the East,

$$\begin{aligned}
\ell^E &= \left(\frac{\sigma}{\sigma-1}\right)^{-\sigma} w^{E(1-\sigma)}\left[a^{M(1-\sigma)}q^M\left(\frac{c^W\ell^W}{\bar{P}^{W(1-\sigma)}}\tau^{EW(1-\sigma)}+\frac{c^E\ell^E}{\bar{P}^{E(1-\sigma)}}+\frac{c^{RoW}(1-\ell^W-\ell^E)}{\bar{P}^{RoW(1-\sigma)}}\tau^{ERoW(1-\sigma)}\right)\right.\\
&+ \left. a^{E(1-\sigma)}q^E\left(\frac{c^W\ell^W}{\bar{P}^{W(1-\sigma)}}\tau^{EW(1-\sigma)}+\frac{c^E\ell^E}{\bar{P}^{E(1-\sigma)}}+\frac{c^{RoW}(1-\ell^W-\ell^E)}{\bar{P}^{RoW(1-\sigma)}}\tau^{ERoW(1-\sigma)}\right)\right]\\
&+ \frac{I^{M\frac{1}{1-\alpha}}}{\gamma^M}\frac{Q^W(t)}{\hat{Q}^W(t)^\phi L(t)}+\frac{I^{E\frac{1}{1-\alpha}}}{\gamma^E}\frac{Q^{(M+E)}(t)}{\hat{Q}^E(t)^\phi L(t)}. \qquad \text{(B.22)}
\end{aligned}$$

and finally, in the RoW,

$$\begin{aligned}
1-\ell^W-\ell^E &= \left(\frac{\sigma}{\sigma-1}\right)^{-\sigma} a^{RoW(1-\sigma)}q^{RoW}w^{RoW(1-\sigma)}\left(\frac{c^W\ell^W}{\bar{P}^{W(1-\sigma)}}\tau^{RoWW(1-\sigma)}+\frac{c^E\ell^E}{\bar{P}^{E(1-\sigma)}}\tau^{RoWE(1-\sigma)}\right.\\
&+ \left.\frac{c^{RoW}(1-\ell^W-\ell^E)}{\bar{P}^{RoW(1-\sigma)}}\right)+\frac{I^{RoW\frac{1}{1-\alpha}}}{\gamma^{RoW}}\frac{Q(t)}{\hat{Q}^{RoW}(t)^\phi L(t)}, \qquad \text{(B.23)}
\end{aligned}$$

Quality aggregates. As in the benchmark model, the average quality index $Q(t)$ equals the sum of the sectoral quality aggretates

$$\begin{aligned}
Q(t) &= \int_{\omega^W} q(\omega,t)d\omega+\int_{\omega^E} q(\omega,t)d\omega+\int_{\omega^M} q(\omega,t)d\omega+\int_{\omega^{RoW}} q(\omega,t)d\omega\\
&= Q^W(t)+Q^E(t)+Q^M(t)+Q^{RoW}(t), \qquad \text{(B.24)}
\end{aligned}$$

which gives the condition $1=q^W(t)+q^E(t)+q^M(t)+q^{RoW}(t)$. With the RoW innovating and taking over the sectoral leadership from other regions, innovation in the RoW enters the conditions for the change in quality aggregates in the West, the East, the RoW and of the sectors dominated by multinationals. We summarise the conditions below as

$$\begin{aligned}
\dot{Q}^W(t) &= \int_{\omega^W}[\lambda^{(\sigma-1)(j(\omega,t)+1)}-\lambda^{(\sigma-1)j(\omega,t)}]I^W d\omega+\int_{\omega^E+\omega^M+\omega^{RoW}}\lambda^{(\sigma-1)(j(\omega,t)+1)}I^W d\omega \\
&- \int_{\omega^W}\lambda^{(\sigma-1)j(\omega,t)}I^M d\omega-\int_{\omega^W}\lambda^{(\sigma-1)j(\omega,t)}I^{RoW} d\omega \\
&= (\lambda^{\sigma-1}-1)I^W Q^W(t)+\lambda^{\sigma-1}I^W(Q^E(t)+Q^M(t)+Q^{RoW}(t))-I^M Q^W(t)-I^{RoW}Q^W(t). \qquad \text{(B.25)} \\
\dot{Q}^{RoW}(t) &= \int_{\omega^{RoW}}[\lambda^{(\sigma-1)(j(\omega,t)+1)}-\lambda^{(\sigma-1)j(\omega,t)}]I^{RoW} d\omega+\int_{\omega^E+\omega^M+\omega^W}\lambda^{(\sigma-1)(j(\omega,t)+1)}I^{RoW} d\omega \\
&- \int_{\omega^{RoW}}\lambda^{(\sigma-1)j(\omega,t)}I^W d\omega, \\
&= (\lambda^{\sigma-1}-1)I^{RoW}Q^{RoW}(t)+\lambda^{\sigma-1}I^{RoW}(Q^E(t)+Q^M(t)+Q^W(t))-I^W Q^{RoW}(t). \qquad \text{(B.26)} \\
\dot{Q}^E(t) &= \int_{\omega^E}[\lambda^{(\sigma-1)(j(\omega,t)+1)}-\lambda^{(\sigma-1)j(\omega,t)}]I^E d\omega+\int_{\omega^M}\lambda^{(\sigma-1)(j(\omega,t)+1)}I^E d\omega \\
&- \int_{\omega^E}\lambda^{(\sigma-1)j(\omega,t)}I^W d\omega-\int_{\omega^E}\lambda^{(\sigma-1)j(\omega,t)}I^{RoW} d\omega \\
&= (\lambda^{\sigma-1}-1)I^E Q^E(t)+\lambda^{\sigma-1}I^E Q^M(t)-I^W Q^E(t)-I^{RoW}Q^E(t), \qquad \text{(B.27)} \\
\dot{Q}^M(t) &= \int_{\omega^W}\lambda^{(\sigma-1)j(\omega,t)}I^M d\omega-\int_{\omega^M}\lambda^{(\sigma-1)j(\omega,t)}I^W d\omega-\int_{\omega^M}\lambda^{(\sigma-1)j(\omega,t)}I^E d\omega-\int_{\omega^M}\lambda^{(\sigma-1)j(\omega,t)}I^{RoW} d\omega \\
&= I^M Q^W(t)-(I^W+I^E+I^{RoW})Q^M(t) \qquad \text{(B.28)}
\end{aligned}$$

The average product quality of all the production in the East is given by $Q^{EM}(t)=Q^E(t)+Q^M(t)$ and it evolves according to

$$\begin{aligned}
\dot{Q}^{EM}(t) &= \dot{Q}^E(t)+\dot{Q}^M(t) \\
&= (\lambda^{\sigma-1}-1)I^E Q^{EM}+I^M Q^W(t)-(I^W+I^{RoW})(Q^E(t)+Q^M(t)). \qquad \text{(B.29)}
\end{aligned}$$

Finally, adding (B.25)-(B.28) and dividing by $Q(t)$ we obtain the expression for the growth of the average quality $Q(t)$ as

$$\frac{\dot{Q}(t)}{Q(t)}=(\lambda^{\sigma-1}-1)\left[I^W(t)+\left(q^E(t)+q^M(t)\right)I^E(t)+I^{RoW}(t)\right]=g(t). \qquad \text{(B.30)}$$

Competitive equilibrium. The competitive equilibrium for this economy is thus characterised by the following. The free entry and arbitrage conditions (B.20) for the West, the East, the Rest of the World and multinationals incumbent firms, the firm value for all countries (12), the aggregate assets for all countries, (22) plus one additional identical expression for the rest of the world. The laws of motion for quality (B.24), (B.25), (B.26), (B.27), (B.28), and (B.30), the market clearing conditions (B.21), (B.22), (B.23), the Euler equation (3), and two of the aggregate budget constrains (21), $c^{RoW}=w^{RoW}+(r^{RoW}-n)\mathscr{A}^{RoW}-\dot{\mathscr{A}}^{RoW}-T^{Row}$, as trade balanced implies that once two of them are satisfied the third is as well. These 23 equilibrium equations determine 23 endogenous variables, c^W, c^E, c^{RoW}, I^W, I^E, I^M,I^{RoW}, w^E, w^{RoW}, v^W, v^E, v^M, v^{RoW}, $\mathscr{A}^W$, $\mathscr{A}^E$, $\mathscr{A}^{RoW}$, Q^W, Q^E, Q^M, Q^{RoW}, Q, g and r.

B.3.2 Balanced growth path

Balanced growth free entry conditions. As noted in the benchmark model description for the BGP, with constant wages and innovation arrival rates, $\dot{v}^k(t)/v^k(t) = -\dot{A}^k(t)/A^k(t) = -\phi g$, for $k = W, E, RoW, M$. Substituting for profits and the marginal product of research (MRI) in (B.20), we determine the BGP free entry conditions in three different types of sectors (firms) as

$$\frac{(1-s^W)}{\gamma^W}\frac{Q(t)}{\hat{Q}^W(t)^\phi L(t)} = \frac{\tilde{\sigma} a^{W(1-\sigma)}\left(\frac{c^W\ell^W}{(\bar{P}^W)^{(1-\sigma)}} + \frac{c^E\ell^E}{(\bar{P}^E)^{(1-\sigma)}}\tau^{WE(1-\sigma)} + \frac{c^{RoW}(1-\ell^W-\ell^E)}{(\bar{P}^{RoW})^{(1-\sigma)}}\tau^{WRoW(1-\sigma)}\right)}{\rho + I^W + I^{RoW} + \phi g} I^{W\frac{\alpha}{\alpha-1}} \quad \text{for } \omega \in \omega^W, \tag{B.31}$$

where $Q(t)/\left(\hat{Q}^W(t)^\phi L(t)\right) = q^{W(-\beta\phi)}x$ is stationary and $\tilde{\sigma} = \frac{\sigma^{-\sigma}}{(\sigma-1)^{(1-\sigma)}}$.

$$\begin{aligned}\frac{(1-s^E)w^E}{\gamma^E}\frac{Q(t)}{\hat{Q}^E(t)^\phi L(t)} = \frac{\tilde{\sigma} a^{E(1-\sigma)} w^{E(1-\sigma)}}{\rho + I^W + I^E + I^{RoW} + \phi g}\Bigg(\frac{c^W\ell^W}{(\bar{P}^W)^{(1-\sigma)}}\tau^{EW(1-\sigma)} \\ + \frac{c^E\ell^E}{(\bar{P}^E)^{(1-\sigma)}} + \frac{c^{RoW}(1-\ell^W-\ell^E)}{(\bar{P}^{RoW})^{(1-\sigma)}}\tau^{ERoW(1-\sigma)}\Bigg) I^{E\frac{\alpha}{\alpha-1}} \quad \text{for } \omega \in \omega^E,\end{aligned} \tag{B.32}$$

where $Q(t)/\left(\hat{Q}^E(t)^\phi L(t)\right) = (q^E + q^M)^{(-\beta\phi)}x$ is stationary.

$$\begin{aligned}\frac{(1-s^{RoW})w^{RoW}}{\gamma^{RoW}}\frac{Q(t)}{\hat{Q}^{RoW}(t)^\phi L(t)} = \frac{\tilde{\sigma} a^{RoW(1-\sigma)} w^{RoW(1-\sigma)}}{\rho + I^W + I^{RoW} + \phi g}\Bigg(\frac{c^W\ell^W}{(\bar{P}^W)^{(1-\sigma)}}\tau^{RoWW(1-\sigma)} \\ + \frac{c^E\ell^E}{(\bar{P}^E)^{(1-\sigma)}}\tau^{RoWE(1-\sigma)} + \frac{c^{RoW}(1-\ell^W-\ell^E)}{(\bar{P}^{RoW})^{(1-\sigma)}}\Bigg) I^{RoW\frac{\alpha}{\alpha-1}} \quad \text{for } \omega \in \omega^{RoW},\end{aligned} \tag{B.33}$$

where $Q(t)/\left(\hat{Q}^{RoW}(t)^\phi L(t)\right) = q^{RoW(-\beta\phi)}x$ is stationary.

$$\begin{aligned}\frac{(1-s^M)w^E}{\gamma^M}\frac{Q(t)}{\hat{Q}^W(t)^\phi L(t)} = \tilde{\sigma}\Bigg[\frac{a^{M(1-\sigma)}w^{E(1-\sigma)}}{\rho + I^W + I^E + I^{RoW} + \phi g}\left(\frac{c^W\ell^W}{(\bar{P}^W)^{(1-\sigma)}}\tau^{EW(1-\sigma)} + \frac{c^E\ell^E)}{(\bar{P}^E)^{(1-\sigma)}} + \frac{c^{RoW}(1-\ell^W-\ell^E)}{(\bar{P}^{RoW})^{(1-\sigma)}}\tau^{ERoW(1-\sigma)}\right) \\ - \frac{a^{W(1-\sigma)}}{\rho + I^W + I^{RoW} + \phi g}\left(\frac{c^W\ell^W}{(\bar{P}^W)^{(1-\sigma)}} + \frac{c^E(1-\ell^W)}{(\bar{P}^E)^{(1-\sigma)}}\tau^{WE(1-\sigma)}\frac{c^{RoW}(1-\ell^W-\ell^E)}{(\bar{P}^{RoW})^{(1-\sigma)}}\tau^{ERoW(1-\sigma)}\right)\Bigg] I^{M\frac{\alpha}{\alpha-1}} \\ \text{for } \omega \in \omega^M\end{aligned} \tag{B.34}$$

Quality aggregates on the BGP. Equating the growth of quality aggregates in the West and in the East, $\frac{\dot{Q}^W(t)}{Q^W(t)} = \frac{\dot{Q}^{EM}(t)}{Q^{EM}(t)}$, to satisfy the invariance of sectoral composition, we obtain

$$\lambda^{\sigma-1}\frac{I^W}{q^W} = \frac{I^M}{q^M + q^E} + (\lambda^{\sigma-1} - 1)I^E. \tag{B.35}$$

Similarly, the growth rate of quality aggregates of the eastern innovating firms in sectors with previous FDI and the multinational firms has to be the same in a steady-state equilibrium, $\frac{\dot{Q}^E(t)}{Q^E(t)} = \frac{\dot{Q}^M(t)}{Q^M(t)}$, which yields the condition

$$\frac{q^W}{q^M + q^E} = \lambda^{\sigma-1} \frac{I^E}{I^M} \frac{q^M}{q^E}. \tag{B.36}$$

Finally, quating the growth of quality aggregates in the West and in the RoW, $\frac{\dot{Q}^W(t)}{Q^W(t)} = \frac{\dot{Q}^{RoW}(t)}{Q^{RoW}(t)}$, we obtain

$$\lambda^{\sigma-1}\left(\frac{I^W}{q^W} - \frac{I^{RoW}}{q^{RoW}}\right) = I^M. \tag{B.37}$$

Sectoral composition. In steady state, constant shares of the four types of sectors in the economy are required. In the West, $\omega^W(I^M + I^{RoW}) = (\omega^M + \omega^E + \omega^{RoW})I^W$ which gives the stability condition $\omega^W = \frac{I^W}{I^M + I^W + I^{RoW}}$. Similarly, in the RoW, $\omega^{RoW} I^W = (\omega^M + \omega^E + \omega^W)I^{RoW}$ which yields the stability condition $\omega^{RoW} = \frac{I^{RoW}}{I^W + I^{RoW}}$. The condition for the sectors with eastern leadership is given by $\omega^E(I^W + I^{Row}) = \omega^M I^E$, which, using $\omega^W + \omega^M + \omega^E + \omega^{RoW} = 1$, yields $\omega^E = \frac{I^E}{I^E + I^W + I^{RoW}} - \frac{I^E I^W}{I^M + I^W + I^{RoW}} - \frac{I^E I^{RoW}}{I^W + I^{RoW}}$. Finally, the share of sectors with production by multinationals is given by $\omega^M = 1 - \frac{I^W(1-I^E)}{I^M + I^W + I^{RoW}} - \frac{I^E}{I^E + I^W + I^{RoW}} - \frac{I^{RoW}(1-I^E)}{I^W + I^{RoW}}$.

Equations (B.31)- (B.34) for the four types of sectors, (B.3.2)-(B.37), (B.30) and (B.21)-(B.23) define a set of BGP conditions for endogenous variables c^W, c^E, c^{RoW} I^W, I^E, I^M, I^{RoW}, w^E, w^{RoW}, q^W, q^{RoW}, q^M and q^E. We derive the expressions for per capita assets and expenditures below.

Assets and expenditures. As in the benchmark model, we assume that western households finance both the innovative and adaptive R&D in the West and the East and thus receive, in the form of dividends, the profits of firms operating in the West and the profits of multinational firms. The total stock of per capita assets is given by

$$\begin{aligned}\mathscr{A}^W(t) &= \int_{\omega^W+\omega^M} \frac{v^W(\omega,t)}{L^W(t)} d\omega + \int_{\omega^M} \frac{v^M(\omega,t) - v^W(\omega,t)}{L^W(t)} d\omega \\ &= (1-s^W)\frac{I^{W\frac{\alpha}{1-\alpha}}}{\gamma^W} \frac{Q^W(t)}{\hat{Q}^W(t)^\phi L^W(t)} + (1-s^M)w^E \frac{I^{M\frac{\alpha}{1-\alpha}}}{\gamma^M} \frac{Q^M(t)}{\hat{Q}^W(t)^\phi L^W(t)}.\end{aligned} \tag{B.38}$$

where $\frac{Q^W(t)}{\hat{Q}^W(t)^\phi L^W(t)} = q^{W(1-\beta\phi)} x/\ell^W$ and $\frac{Q^M(t)}{\hat{Q}^W(t)^\phi L^W(t)} = q^M q^{W(-\beta\phi)} x/\ell^W$ are stationary.

The total assets value in the East comes from eastern firms' market leadership through innovation through the E sectors. Then, the total stock of per capita assets is derived as

$$\mathscr{A}^E = \int_{\omega^E} \frac{v^E(\omega,t)}{L^E} d\omega = (1-s^E)w^E \frac{I^{E\frac{\alpha}{1-\alpha}}}{\gamma^E} \frac{Q^E(t)}{\hat{Q}^E(t)^\phi L^E(t)}.$$

where $\frac{Q^E(t)}{\hat{Q}^E(t)^\phi L^E(t)} = q^{E(1-\beta\phi)} x/\ell^E$ is stationary.

Finally, the total assets value in the RoW consists of the RoW firms' value created through innovation in the *RoW* sectors. The total stock of per capita assets is given by

$$
\begin{aligned}
\mathscr{A}^{RoW}(t) &= \int_{\omega^{RoW}} \frac{v^{RoW}(\omega,t)}{L^{RoW}(t)} d\omega = \int_{\omega^{RoW}} \frac{v^{RoW}(\omega,a)e^{-\phi g(t-a)}}{L^{RoW}(t)} d\omega \\
&= \int_{\omega^{RoW}} (1-s^{RoW}) \frac{w^{RoW} I^{RoW \frac{\alpha}{1-\alpha}}}{\gamma^{RoW} L^{RoW}(t)} \frac{q(\omega,a)}{\hat{Q}^{RoW}(a)^{\phi}} e^{-\phi g(t-a)} d\omega \\
&= (1-s^{RoW}) \frac{w^{RoW} I^{RoW \frac{\alpha}{1-\alpha}}}{\gamma^{RoW} L^{RoW}(t)} \frac{\int_{\omega^{RoW}} q(\omega,a)}{(\hat{Q}^{RoW}(t)e^{-g(t-a)})^{\phi}} e^{-\phi g(t-a)} d\omega \\
&= (1-s^{RoW}) \frac{w^{RoW} I^{RoW \frac{\alpha}{1-\alpha}}}{\gamma^{RoW}} \frac{Q^{RoW}(t)}{\hat{Q}^{RoW}(t)^{\phi} L^{RoW}(t)}.
\end{aligned} \tag{B.39}
$$

where $\frac{Q^{RoW}(t)}{\hat{Q}^{RoW}(t)^{\phi} L^{RoW}(t)} = q^{RoW(1-\beta\phi)} x/\ell^{RoW}$ is stationary.

Using the conditions above in the expressions for per-capita consumer expenditure (21), we obtain

$$
\begin{aligned}
c^{W} &= 1+(\rho-n)\left[(1-s^{W}) \frac{Q^{(W+M)}}{\gamma^{W} \hat{Q}^{W}(t)^{\phi}} \frac{I^{W \frac{\alpha}{1-\alpha}}}{L^{W}(t)} + (1-s^{M}) w^{E} \frac{Q^{M}}{\gamma^{M} \hat{Q}^{W}(t)^{\phi}} \frac{I^{M \frac{\alpha}{1-\alpha}}}{L^{W}(t)}\right] \\
&- s^{W} I^{W \frac{1}{1-\alpha}} \frac{Q(t)}{\gamma^{W} \hat{Q}^{W}(t)^{\phi} L^{W}(t)},
\end{aligned} \tag{B.40}
$$

where the ratio of the growing variables is stationary, as shown above.

$$
\begin{aligned}
c^{E} &= w^{E}\left(1+(\rho-n)\left[(1-s^{E}) \frac{Q^{E}(t)}{\gamma^{E} \hat{Q}^{E}(t)^{\phi}} \frac{I^{E \frac{\alpha}{1-\alpha}}}{L^{E}(t)}\right]\right. \\
&- \left. s^{E} I^{E \frac{1}{1-\alpha}} \frac{Q^{(M+E)}(t)}{\gamma^{E} \hat{Q}^{E}(t)^{\phi} L^{E}(t)} - s^{M} I^{M \frac{1}{1-\alpha}} \frac{Q^{W}(t)}{\gamma^{M} \hat{Q}^{W}(t)^{\phi} L^{E}(t)}\right),
\end{aligned} \tag{B.41}
$$

for the West and the East, respectively. Expression $\frac{Q^{M+E}(t)}{\hat{Q}^{E}(t)^{\phi} L^{E}(t)} = \left(Q^{M} q^{E(-\beta\phi)} q^{E(1-\beta\phi)}\right) x/\ell^{E}$ is stationary. Similarly for the RoW, the per-capita expenditure condition is derived as

$$
\begin{aligned}
c^{RoW} &= w^{RoW}\left(1+(\rho-n)\left[(1-s^{RoW}) \frac{Q^{RoW}(t)}{\gamma^{RoW} \hat{Q}^{RoW}(t)^{\phi}} \frac{I^{RoW \frac{\alpha}{1-\alpha}}}{L^{RoW}(t)}\right]\right. \\
&- \left. s^{RoW} I^{RoW \frac{1}{1-\alpha}} \frac{Q^{(RoW)}(t)}{\gamma^{RoW} \hat{Q}^{RoW}(t)^{\phi} L^{RoW}(t)}\right),
\end{aligned} \tag{B.42}
$$

with the last term in parenthesis capturing the subsidised part of the innovation cost in the RoW, financed by the RoW lump-sum tax.

Balanced growth equilibrium. The balanced growth path is then characterised by the following. The free entry and arbitrage conditions (B.31), (B.32), (B.33), (B.32) for the West, the East and the RoW, the quality shares (B.3.2), (B.36), (B.37) plus $q^W + q^M + q^E + Q^{RoW} = 1$, the growth equation $g = n/(1-\pi)$ together with (B.30), the market clearing conditions (B.21), (B.22), (B.23) one of the aggregate budget constraints (B.40)-(B.41)-(B.42), as trade balanced implies that once one of them is satisfied the other is as well, and the Euler equation (3). These 16 equilibrium conditions determine 16 endogenous variables, c^W, c^E, c^{RoW}, I^W, I^E, I^M, I^{RoW}, w^E, w^{RoW}, q^W, q^E, q^M, q^{RoW}, r, g and x.

B.4 Calibration of three-region model

We need to recalibrate the model to discipline the four new parameters. There is one new innovation efficiency parameter γ^{RoW}. We adopt some simplifying assumptions regarding the parameterisation, for the purpose of ensuring existence of the solution to the model. We firstly fix the manufacturing productivity to be the same across E and R, meaning that $a^E = a^M = a^{RoW}$. Secondly, we assume the countries to be all of the same size in terms of population, meaning $\ell^W = \ell^E = \ell^{RoW} = 1/3$. We take s^{RoW} from the OECD B-index data on large firms as in the baseline parametrisation. We assume that the parameter governing the local nature of R&D spillovers is the same for all sectors and regions, that is, $\beta^k = \beta$. The new key parameter to discipline is that governing innovation efficiency in innovative R&D, γ^{RoW}, which contributes to the distribution of leadership. We consider an RoW region consisting of four economies, the USA, Canada, Japan and China.

As in the benchmark model, we use the calculated share of sectors with Western leadership in the 3-region world economy (31%) that we obtained from the OECD AMNE database for the 2005-2016 period. Furthermore, we calculate the total share of industries with Eastern leadership (ω^E) as the share of output of Eastern-owned firms in the East in the total world output which amounts to 2% of the world economy. The total share of industries with RoW leadership (ω^{RoW}) is the share of output of RoW-owned firms in the RoW in the total world output which amounts to 66%. The residual ($1-\omega^W-\omega^E-\omega^{RoW}$) represents the share of industries with multinational subsidiary firms production in the East (less than 1%). When calculating the sectoral shares, we exclude the FDI of the RoW and the East in the other regions from the total world output, as well as the FDI from the countries outside of our model.

In total, our analysis necessitates the calibration of 10 parameters ($\sigma, \beta, \lambda, \alpha, \phi$ as well as the R&D productivities and manufacturing productivities). We target similar data moments as in the 2 region model — relative wages, sectoral shares, R&D spending and employment shares in the West, as well as innovation to subsidy elasticities in each region. Table B.1 reports the parameter values and the model fit.

Table B.1: Calibration summary (3-region economy)

External parameters	Value	Source
Interest rate ($r = \rho$)	0.04	Eurostat, 2001-2013
Population growth rate (n)	0.54%	OECD&Eurostat, 1961-2013
R&D subsidy, West (s^W)	12.2%	OECD, 2011
R&D subsidy, East (s^E)	9.70%	OECD, 2011
R&D subsidy, *RoW* (s^{RoW})	13.0%	OECD, 2011
Relative labour size, West (l^W)	0.33	Simplifying assumption
Relative labour size, *RoW* (l^{RoW})	0.33	Simplifying assumption
Calibrated parameters	Value	
Utility f-n parameter (σ)	2.39	
Innovative R&D productivity parameter, West (γ^W)	0.83	
Innovative R&D productivity parameter, East (γ^E)	0.33	
Innovative R&D productivity parameter, MNE (γ^M)	0.21	
Innovative R&D productivity parameter, *RoW* (γ^{RoW})	0.40	
Manufacturing productivity, East and *RoW* ($a^E = a^M = a^R$)	0.83	
Spillover parameter (β)	0.80	
Quality jump size (λ)	1.46	
Decreasing returns (α)	0.54	
Spillover (ϕ)	0.70	
Moments	Data (Model)	Source
East relative wage (w^E)	0.56 (0.38)	OECD, 2015
RoW relative wage (w^{RoW})	0.84 (0.79)	OECD, 2015
Share of sectors, Western leadership (ω^W)	31.36% (24.06%)	OECD, 2005-2016
Share of sectors, Eastern leadership (ω^E)	2.14% (7.41%)	OECD, 2005-2016
Share of sectors, MNE leadership (ω^M)	0.52% (7.68%)	OECD, 2005-2016
Share of sectors, *RoW* leadership (ω^{RoW})	65.98% (60.86%)	OECD, 2005-2016
West R&D expenditure/GDP	4.57% (5.69%)	OECD, 2015
West share of labour in R&D	3.13% (7.09%)	Eurostat, 2015
West innovation elasticity to subsidy	[1.2, 2.9] (1.34)	Akcigit et al. (2018a)
East innovation elasticity to subsidy	[1.2, 2.9] (0.11)	Akcigit et al. (2018a)
RoW innovation elasticity to subsidy	[1.2, 2.9] (2.63)	Akcigit et al. (2018a)

C Computational Appendix

The following gives the algorithm for finding the transition path after a policy change in the baseline 2 region model.

1. Designate the finite differences time interval length $\Delta > 0$. Increments of this object will be indexed by δ. Conjecture the number of intervals until the new steady state is reached after a reform $T \in \mathbb{N}$.

2. Solve for the pre- and post-reform steady states of the model. Solving for a steady state gives a list of endogeneous objects

$$\vec{\Gamma} = (I^W, I^E, I^M, w^E, q^W, q^E, q^M, \mathscr{A}^W, \mathscr{A}^E, c^W, c^E, x)$$

where $x^W = \frac{Q(t)^{1-\phi}}{L(t)}$. Denote the sets of objects found in the pre and post-reform steady states by $\vec{\Gamma}_0$ and $\vec{\Gamma}_{T\Delta}$ respectively.

3. Conjecture the set of objects

$$\vec{\Psi} = \{I^W_\delta, I^E_\delta, I^M_\delta, w^E_\delta, r^W_\delta, r^E_\delta\}_{\delta=\Delta}^{T\Delta} \tag{C.1}$$

for $\delta = \Delta, 2\Delta, 3\Delta, ..., T\Delta$ where r^K_δ is the riskless rate in country $K \in \{W, E\}$.

4. Given conjecture (C.1), iterate forwards on the laws of motion for the quality shares (B.4), (B.5) and (B.6). This yields the sequence $\vec{q} = \{q^W_\delta, q^E_\delta, q^M_\delta\}_{\delta=\Delta}^{T\Delta}$ as well as $\vec{G} = \{g^W_\delta, g^E_\delta, g^M_\delta, g_\delta\}_{\delta=\Delta}^{T\Delta}$ where the latter objects are the growth rates in the quality of Western-led, Eastern-led, multinational-led and all industries, respectively.

5. Use the definition of x, alongside $\vec{q}$ and $\vec{G}$ to obtain sequence $\vec{X} = \{x_\delta\}_{\delta=\Delta}^{T\Delta}$.

6. Find the sequence $\vec{T} = \{T^W_\delta, T^E_\delta\}_{\delta=\Delta}^{T\Delta}$ of tax payments from the household using $\vec{\Psi}$, $\vec{q}$ and $\vec{X}$.

7. Solve the household problem in each country $K \in \{W, E\}$ to obtain objects $\vec{A}^D = \{\mathscr{A}^W_\delta, \mathscr{A}^E_\delta\}_{\delta=\Delta}^{T\Delta}$ (asset demand) and $\vec{C} = \{c^W_\delta, c^E_\delta\}_{\delta=\Delta}^{T\Delta}$ (nominal expenditure) as follows.

   (a) Conjecture an impact level of nominal expenditure on goods c^K_Δ.

   (b) Find the level of asset holdings from the household budget constraint (21) with $\vec{T}$ using c^K_δ and $\mathscr{A}^K_{\delta-\Delta}$. The initial condition for assets in the case of $\delta = \Delta$ is $\mathscr{A}^K$ from $\vec{\Gamma}_0$.

   (c) Find the implied value of expenditure next time increment using the Euler equation (3).

   (d) Continue with steps (b) and (c) until reaching time $T\Delta$.

   (e) Check the distance from the terminal steady state asset level found in $\vec{\Gamma}_{T\Delta}$.

(f) Update the initial guess c^K_Δ, return to step (b) and continue until convergence.

8. Find the sequences $\vec{P} = \{\bar{P}^W_\delta, \bar{P}^E_\delta\}_{\delta=\Delta}^{T\Delta}$ using the definitions of the de-trended CPI, $\vec{q}$ and $\vec{\Psi}$.

9. Find the sequence of growth rates in profits $\vec{\Pi} = \{g^W_{\pi,\delta}, g^E_{\pi,\delta}, g^M_{\pi,\delta}\}_{\delta=\Delta}^{T\Delta}$ where $g^K_{\pi,\delta} = \pi^K(\delta)/\pi^K(\delta - \Delta)$ for $K \in \{W,E,M\}$ using (7), $\vec{C}$, $\vec{P}$ and $\vec{\Psi}$.

10. Find the growth in the incumbent value function $\vec{V} = \{g^W_{v,\delta}, g^E_{v,\delta}, g^M_{v,\delta}\}_{\delta=\Delta}^{T\Delta}$ where $g^K_{v,\delta} = v^K(\delta)/v^K(\delta - \Delta)$ by iterating backwards from time $T\Delta$ using $\vec{\Pi}$, $\vec{\Psi}$ and expression (12).

11. Find the supply of assets using $\vec{V}$, $\vec{C}$, $\vec{P}$, $\vec{q}$ and $\vec{\Psi}$ with equation (12) and the expression

$$\widehat{\mathscr{A}^W_\delta}(t) = \int_{\omega^W+\omega^M} \frac{v^W(\omega,t)}{L^W(t)} d\omega + \int_{\omega^M} \frac{v^M(\omega,t) - v^W(\omega,t)}{L^W(t)} d\omega$$
$$\widehat{\mathscr{A}^E_\delta}(t) = \int_{\omega^E} \frac{v^E(\omega,t)}{L^E(t)} d\omega$$

to obtain the sequence $\vec{A}^S = \{\widehat{\mathscr{A}^W_\delta}, \widehat{\mathscr{A}^E_\delta}\}_{\delta=\Delta}^{T\Delta}$.

12. Use $\vec{V}$, $\vec{\Psi}$, $\vec{P}$, $\vec{C}$, $\vec{A}^S$, $\vec{A}^D$ and $\vec{X}$ to compute the distance from free entry, labour market clearing and excess demand for assets in each market and instant in time $\delta = \Delta, 2\Delta, ..., T\Delta$. Then update the objects in $\vec{\Psi}$ accordingly and return to step 4. Repeat until all equilibrium conditions at every moment in time are sufficiently small. If the model has not converged by increment T, increase T and return to step 3.

When computing the transition for the 3 region model, the variables defined above in this appendix change (using the same notation all defined here in Appendix C)

$$\vec{\Gamma} = (I^W, I^E, I^M, I^{RoW}, w^E, w^{RoW}, q^W, q^E, q^M, q^{RoW}, \mathscr{A}^W, \mathscr{A}^E, \mathscr{A}^{RoW}, c^W, c^E, c^{RoW}, x)$$
$$\vec{\Psi} = \{I^W_\delta, I^E_\delta, I^M_\delta, I^{RoW}_\delta, w^E_\delta, w^{RoW}_\delta, r^W_\delta, r^E_\delta, r^{RoW}_\delta\}_{\delta=\Delta}^{T\Delta}$$
$$\vec{q} = \{q^W_\delta, q^E_\delta, q^M_\delta, q^{RoW}_\delta\}_{\delta=\Delta}^{T\Delta}$$
$$\vec{G} = \{g^W_\delta, g^E_\delta, g^M_\delta, g^{RoW}_\delta, g_\delta\}_{\delta=\Delta}^{T\Delta}$$
$$\vec{T} = \{T^W_\delta, T^E_\delta, T^{RoW}_\delta\}_{\delta=\Delta}^{T\Delta}$$
$$\vec{A}^D = \{\mathscr{A}^W_\delta, \mathscr{A}^E_\delta, \mathscr{A}^{RoW}_\delta\}_{\delta=\Delta}^{T\Delta}$$
$$\vec{C} = \{c^W_\delta, c^E_\delta, c^{RoW}_\delta\}_{\delta=\Delta}^{T\Delta}$$
$$\vec{P} = \{\bar{P}^W_\delta, \bar{P}^E_\delta, \bar{P}^{RoW}_\delta\}_{\delta=\Delta}^{T\Delta}$$
$$\vec{\Pi} = \{g^W_{\pi,\delta}, g^E_{\pi,\delta}, g^M_{\pi,\delta}, g^{RoW}_{\pi,\delta}\}_{\delta=\Delta}^{T\Delta}$$
$$\vec{V} = \{g^W_{v,\delta}, g^E_{v,\delta}, g^M_{v,\delta}, g^{RoW}_{v,\delta}\}_{\delta=\Delta}^{T\Delta}$$
$$\vec{A}^S = \{\widehat{\mathscr{A}^W_\delta}, \widehat{\mathscr{A}^E_\delta}, \widehat{\mathscr{A}^{RoW}_\delta}\}_{\delta=\Delta}^{T\Delta}.$$

The steps used in the algorithm are then the same as in the 2 region model. Notice at Step 7, one must then shoot forwards on the household Euler equations for each of the three regions.