



Innovation union: costs and benefits of innovation policy coordination

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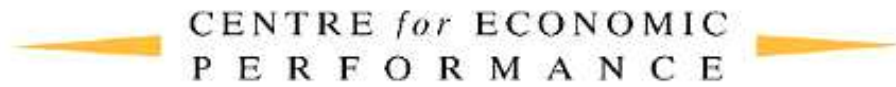
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**Innovation Union: Costs and Benefits of
Innovation Policy Coordination**

**Teodora Borota
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Abstract

In this paper, we document large heterogeneity in innovation policy and performance between old and new EU member states, and present firm-level evidence on the close link between foreign direct investment (FDI) spillovers and eastern European firms' innovation. Guided by these facts and motivated by the pressing debate on further EU integration, we build a two-region endogenous growth model to analyse the gains from innovation policy cooperation in an economic union. The two regions, the West (the old members) and the East (the new post-2004 members), feature firms competing in innovation for market leadership, are integrated via free trade and costly technology transfer via FDI and have different innovation performance and policy. Calibrating the model to reproduce key features of the EU economy, we compare the outcomes of an East-West R&D subsidy war with a cooperation scenario with unified subsidy across regions, and obtain three main results. First, we find that the dynamic gains spurring from the impact of cooperation on the economy's growth rate are sizable and substantially larger than the static gains obtained internalising the strategic motive for subsidies. Second, our model suggests that the presence of FDI and multinational production alleviates the strategic motive and increases the gains from cooperation. Third, separating FDI and innovation policy generates larger gains from cooperation, a policy complementarity driven by the knowledge spillovers carried by FDI.

Key words: Optimal innovation policy, growth theory, international policy coordination, EU integration, FDI spillovers.

JEL Codes: O41, O31, O38, F12, F42 F43

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1 Introduction

The recent financial crises have increased the demand for stronger international economic policy coordination on the one hand, and triggered movements toward more policy independence on the other. While some European countries are promoting an ‘ever closer union’ agenda of further policy coordination, in a historical referendum the UK voted to terminate its EU membership. While there is sufficient consensus that trade integration should not be reversed, less agreement can be found on the virtues of coordination in other areas such as banking, fiscal and innovation policies. In the aftermath of the 2008 financial crisis, the debate on the completion of Europe’s Economic and Monetary Union (EMU) intensified around the needs and the breadth of future fiscal and banking union (Berger et al., 2018).

In 2010, the EU launched the Innovation Union, a flagship initiative of the Europe 2020 strategy. An ambitious and wide plan spanning from the creation of a single market for innovation via, for example, the introduction of the Unitary Patent, a procedure aimed at radically cutting the bureaucratic cost of patenting in the EU, to a strong financial support of innovative firms, grant/subsidies for innovative small-medium enterprises (SME instruments) and a specific innovation procurement budget (European Commission, 2015). Moreover, the recent Commission’s 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). These and other Commission’s initiatives can be interpreted as an initial plan to move toward some degree of unification of innovation policy.

Motivated by these political and institutional developments, this paper provides a macroeconomic framework to evaluate the effects of tax and direct government support for innovation and assess the costs and benefits of policy coordination in an economic union. One fundamental task in exploring these issues is to identify the key structural difference 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 externalities that the policy tools are set forth to tackle.

We document large differences between EU members in innovation performances and in innovation policy. These differences are especially pronounced when comparing the new member states (NMS), the eastern European countries that entered with the enlargement started in 2004, and the Old Members, all western European countries. In the period 2008-16, business R&D as a share of GDP is on average 1.31% in western EU countries and 0.5% in eastern countries. The employment share of scientists and engineers in manufacturing is 7.2% on average in the West and 4.2% in the East. An even more striking picture can be obtained looking at innovation output, with over 97% of the patents granted by the European Patent Office (EPO) assigned to a western European firm. Although the differences are still large, some non-negligible innovation dynamism can be observed in eastern Europe: the business R&D share of GDP has almost

doubled between 2008 and 2016 and similar patterns can be observed in the employment share of scientists and engineers and in the EPO patent share.

Along with the recent surge in innovation in the NMS of the EU, we observe a similarly strong increase in inward foreign direct investment. The stock of FDI was about 30% of the total NMS GDP before their entry into the EU and it grew to 70% a decade later, most of it coming from the old EU members. Using firm-level data from the Business Environment and Enterprise Performance Survey (BEEPS) we provide new evidence linking the dynamic innovation performance in NMS, and in other Central and East European Countries, with the surge in FDI and foreign firms' presence. Finally, we document the wide heterogeneity in both government funding of business R&D and indirect support via tax incentives, both between old and new members and within each group.

Guided by these facts and motivated by the recent EU plans to increase innovation policy coordination we set up a two-region, West-East, Schumpeterian growth model of an economic union where trade is free and firms compete in innovation for market leadership. Western firms invest in quality-improving innovation to gain market leadership, once successful they can decide to produce in the high-wage West or incur an adaptive R&D, or FDI, cost to transfer the technology and produce in the low-wage East. Transferring the technology abroad generates local knowledge spillovers which allow eastern firms to start innovating and potentially replace western market leaders. Hence, two opposite forces drive FDI: the labor cost difference between East and West, the *wage gap*, and the difference in Schumpeterian 'creative destruction' in the two regions, the *creative destruction gap*. The higher the innovation in the West compared to the East in a given industry, the lower is the risk for a western firm of losing market leadership when transferring production abroad. Market leadership and production can switch back to the West if one of its firms succeeds in innovating.¹ Innovation in the West and in the East drives the long-run growth rate of the economy which, in the absence of trade costs, is the same for both regions. Adaptive R&D spending has only indirect effects on growth, allowing eastern firms to innovate.

In our benchmark model, we consider one type of policy, R&D subsidies directed to both innovation and adaptive R&D spending (FDI). The reasons for subsidising or taxing R&D in our economy are related to the classical spillovers of Schumpeterian growth models (Aghion and Howitt, 1992, and Grossman and Helpman, 1991b) plus some additional elements related to the open economy and multinational production. When an innovation arrives it benefits consumers immediately, via the higher quality of the good, we dub this the *consumer surplus effect*, but also in the future as future innovations build on past innovations, the intertemporal spillovers or *growth effect*. These effects are not taken into account by innovating firms, thereby

¹The product cycle in each industry occurs in three stages: first through western FDI to the East, then by the eastern innovation to win the sectoral leadership, and finally through leapfrogging of the West which returns the sector's production location to the West.

motivating subsidies to R&D. Moreover, when a firm successfully innovates in a product line, it drives the incumbent firm out of the market. Appropriating the incumbent firm's monopoly profits, the innovating firm reduces the income of the households owning those firms, thereby reducing aggregate consumption which, in turn, lowers the profits of the other leading firms. The innovating firm does not take this into account and is therefore bound to overinvest in R&D. This *business-stealing effect* is a motive for taxing innovation.

In open economy the business stealing produced by innovation can also shift profits and jobs/wages across borders, from foreign firms and workers to their domestic counterparts. This *international business-stealing effect (IBSE)* henceforth) represents a strategic motive for countries to subsidise their firms' R&D (Spencer and Brander, 1983, Eaton and Grossman, 1986). The possibility of offshoring production tames this motive for subsidies. Higher innovation in the West increases the West-East creative destruction gap, thereby increasing the incentives for FDI. More production transfer implies a shift in labor demand and, in some specifications of the model, partially in profits to the East thereby triggering an adverse profit and wage-shifting effect hurting the West. Higher innovation in the East instead, decreases the creative destruction gap, thereby reducing production transfer from the West. Lower FDI implies lower wages and profits in the East and therefore lower incentives to subsidise eastern R&D. Hence, higher integration via production offshoring weakens the strategic motive for subsidies.

We calibrate the model to aggregate and sectorial data to reproduce key facts of the EU economy, which we divide in two regions: the old members, the West in the model, and the new members, the East in the model, which are the eastern European countries that entered after 2004. We first compute the Nash equilibrium R&D subsidies, obtained assuming that the two regions set them non-cooperatively, maximising their own welfare. Second, we calculate a unified subsidy chosen by a EU-level policy maker to maximise the total Union welfare. We find the Nash subsidies to be positive and substantially above those observed in the data. This suggests that the real economy features a substantial underinvestment in innovation, and that the market economy in the model underinvests as well. The domestic business-stealing effect, the externality supporting R&D taxes is weaker than the consumer surplus effect, the growth effect and the strategic motive, the external effects of innovation supporting subsidies. In setting the unified subsidy, the EU-level policy maker internalises the strategic motive, the international business-stealing effect, taking into account the profit and wage shifting role of subsidies. The planner also internalises the effect of each country's subsidy on the other country consumer surplus and growth. We find that the optimal unified subsidy is substantially larger than the Nash subsidy, which suggests that the internalisation of the consumer surplus and the growth effect of innovation are the key driver of R&D policy cooperation.

The welfare gains from a unique EU R&D subsidy are quite large but not equally distributed. Moving from the observed subsidies to the optimal unified subsidy yields a 12% increase in long-run consumption. While the unified subsidy generates a 5.7% gains compared to the non-

cooperative subsidies. The *dynamic gains* spurring from the impact of policy cooperation on the economy's growth rate are substantially larger than the static gains obtainable by internalising consumer surplus and business-stealing effects. Hence, the knowledge externality typical of Schumpeterian models, and the driver of long-run growth in most endogenous growth models, proves to be the key force shaping the gains from R&D policy cooperation.

The gains from cooperation are concentrated in the East while the West does not experience any significant improvement. Since trade is free, internalising the consumer surplus and the growth effect benefits both countries equally. Internalising the international business stealing effect, instead, has unequal welfare implications. In the Nash scenario, the West leads in almost all sectors of the economy, either via direct leadership or via multinationals. Hence, the incentives to cooperate to contain East business stealing are quite low. In parametrisations where the innovation asymmetries between the two regions are smaller, the incentives to cooperate for the West are larger.

FDI alleviates the strategic motive for subsidies and increases the gains from policy cooperation. We show this by increasing the exogenous efficiency of the adaptive R&D technology which leads to more production offshoring. When the regions are more integrated, the rewards for a subsidy war are lower as business stealing is less effective and, consequently, the optimal Nash subsidies are lower as well. The unified subsidy, on the other hand, increases when FDI is more efficient. More FDI leads to more technology transfer and more knowledge spillovers to the East, allowing eastern firms to innovate more efficiently and in more sectors. These stronger external effects on eastern firms are not taken into account in the FDI decisions of western firms, hence there is a stronger reason for the EU-level policy maker to set higher subsidies to internalise them. Consequently, the larger gains from cooperation arise from a stronger need to internalise the growth effect of subsidies in economies that are more integrated via FDI.

Finally, our benchmark economy bundles together an *innovation policy*, the R&D subsidy, and an FDI subsidy, which can be seen as a more standard *trade policy*, as it affects the cost of multinational activity with no direct implications for innovation. In an extension, we consider the subsidy to FDI and the subsidy to R&D separately and quantify the specific gains produced by optimal cooperative innovation and FDI policy. The overall gains from policy cooperation over Nash are now higher than in the baseline scenario. The gains from innovation policy alone are similar to the total gains obtained in the benchmark model, 5.2% of consumption equivalent, but the optimal FDI policy generates an additional 3.2% gains. The complementarity between FDI and R&D subsidies produces the larger gains from cooperation: more FDI leads to stronger international knowledge spillovers which, in turn, strengthen the growth effect on innovation subsidies.

Literature review. The paper is related to several strands of the literature. First, the strategic motive for subsidies has been widely studied in the strategic trade and industrial

policy literature. Contributions focusing on R&D subsidies are the pioneering Spencer and Brander (1983), the following work by Leahy and Neary (1997, 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). In a sequence of recent papers Ossa (2011, 2014, 2015) revisits the key questions in the literature with a modern quantitative approach. Our contribution to this line of work is to cast the analysis in a dynamic framework and show that the impact of innovation policies on productivity growth are quantitatively relevant for the gains from cooperation.² This result echoes the recent finding in the trade and growth literature showing that the *dynamic gains* from trade-induced selection magnifies the gains obtainable in static models with firm heterogeneity (Sampson, 2016, Impullitti and Licandro, 2018, Perla et al., 2015). We extend this result to the gains from policy cooperation and, in addition, we explore the role of multinationals in shaping these gains.

A second related literature is the recent body of quantitative work on the effects of R&D subsidies in closed economy models of endogenous growth, such as Acemoglu and Akcigit (2012), Acemoglu et al. (2018), Akcigit et al. (2016) among others. Open economy applications include Impullitti (2010) and Akcigit et al. (2018), which present quantitative evaluations of the US R&D subsidy policy in the 1980s and 1990s. We follow a similar approach and we contribute focusing on the analysis of the strategic policy and the gains from cooperation, and introducing multinational corporations.

We make contact with a few recent papers analysing FDI and innovation jointly. Arkolakis et al. (2018) build a quantitative model of trade and multinational production in which countries may specialise in innovation and relegate production to other countries via offshoring. They use the model to analyse the effects of changes in FDI costs. Acemoglu et al. (2015) analyse the effects of changes in offshoring costs on technical change and wage inequality in a Ricardian model with multinationals and endogenous technical change. Dinopoulos and Segerstrom (2010) introduce offshoring in a North-South Schumpeterian growth model to study the effects of an increase in the protection of international property rights on innovation and the wage gap between countries. We draw on Dinopoulos and Segerstrom's modeling strategy but allow the firms in the South (the East in our model) to innovate and not simply exogenously imitate northern technology. We present a quantitative analysis, focus on R&D subsidies and analyse the strategic policy interaction between countries and the cost and benefits from policy cooperation.³

²Grossman and Lai (2004) and Kondo (2013) explore the gain from intellectual property rights policy cooperation in endogenous growth models. We complement their theoretical analysis with a quantitative approach, focusing on R&D subsidies, and exploring the role of multinationals.

³Segerstrom and Jakobsson (2017) present a dynamic product-cycle model of North-South trade with multinational production to perform a quantitative analysis of the TRIPS agreements for developing countries but abstract from strategic policy interactions.

Finally, our paper touches upon the empirical literature analysing the link between FDI and innovation. This literature recognises that FDI may act as a vehicle of technology transfer. Local firms may imitate technological innovations introduced by affiliates of multinational firms (Blomstrom and Kokko, 1997). Another major channel of knowledge diffusion may arise when inventors move from subsidiaries of foreign firm to newly started spin-outs. In this case, new entrepreneurs build on knowledge learned when working for their previous employers. According to Audretsch and Feldman (2003), spin-out is one of the most important mechanisms through which knowledge is transmitted locally. Finally, positive productivity spillovers from FDI may take place through backward and forward linkages between foreign affiliates and local firms (Javorcik, 2004).

The evidence on productivity spillovers of FDI though remains mixed (e.g. Gorg and Greenaway, 2014), while recent papers have provided robust evidence of FDI spillovers on domestic firms' innovation. Gorodnichenko et al. (2010) and Gorodnichenko et al. (2015) document strong positive spillover effects from FDI on innovation by domestic firms in Eastern and Central European countries using firm-level data on innovation activity, such as the development of new products or the adoption of new technologies. This empirical evidence is in line with our theoretical model where the establishment of a foreign subsidiary is necessary for the domestically-owned firms to be able to learn the western technology and start innovating upon it. We provide additional evidence showing that the link between FDI and innovation in Eastern European economies is robust to several model specifications.

The rest of the paper is organised as follows: sections 2 presents some stylised facts on R&D policy and innovation in EU states and provides empirical evidence on the link between FDI and innovation. Section 3 presents the model, while the quantitative analysis and the key results are shown in Section 4. Section 5, analyses the robustness of the results to changes in some key parameters and presents some extensions of the main model. Section 6 concludes.

2 Motivating Facts

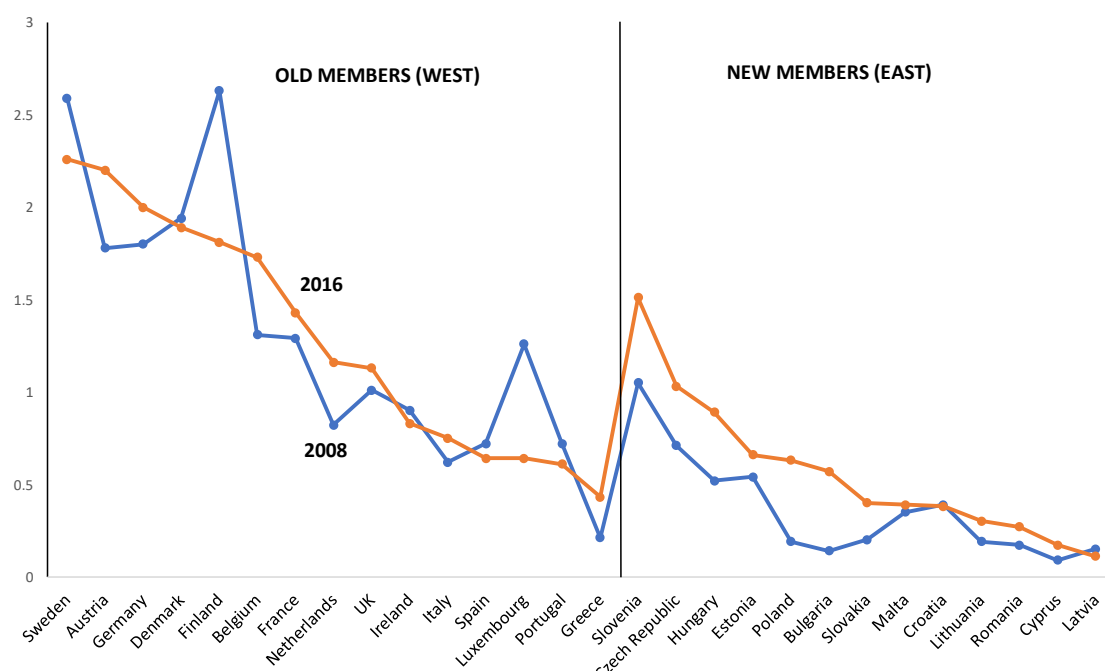
We present a set of descriptive statistics providing motivation for our modelling strategy and empirical support for the quantitative analysis. We document a large heterogeneity in innovation activities and innovation policy across European countries. Moreover, we identify a strong relationship between the presence of western multinationals and the innovation activity performed by local firms in eastern European countries .

2.1 Innovation performance and policy support.

While innovation in Europe is still concentrated in the West, a growing and non-negligible share is performed in the new member states (NMS). Figures 1 and 2 illustrate the differences

in innovation efforts for the year 2008 and 2016 between the old (West) and the new (East) members that have joined the European-Union in May 2004 onwards.⁴ Business R&D as a share of GDP is substantially higher in western compared to eastern EU countries, with an average of 1.31% for the former and 0.5% for the latter in the period 2008-16.⁵ However, several East EU countries, such as Slovenia, the Czech Republic, Hungary, Estonia and Poland show non-negligible and increasing R&D intensity outperforming quite a few old EU members. A similar picture can be obtained looking at the employment share of scientists and engineers in manufacturing. In the period 2008-16, 7.2% of employment in the West was accounted for by scientists and engineers (S&E), while in the East the share is 4.2%. Moreover, the S&E employment share increases in this period in several eastern countries.

Figure 1: Business Enterprise R&D Expenditure (% of GDP)



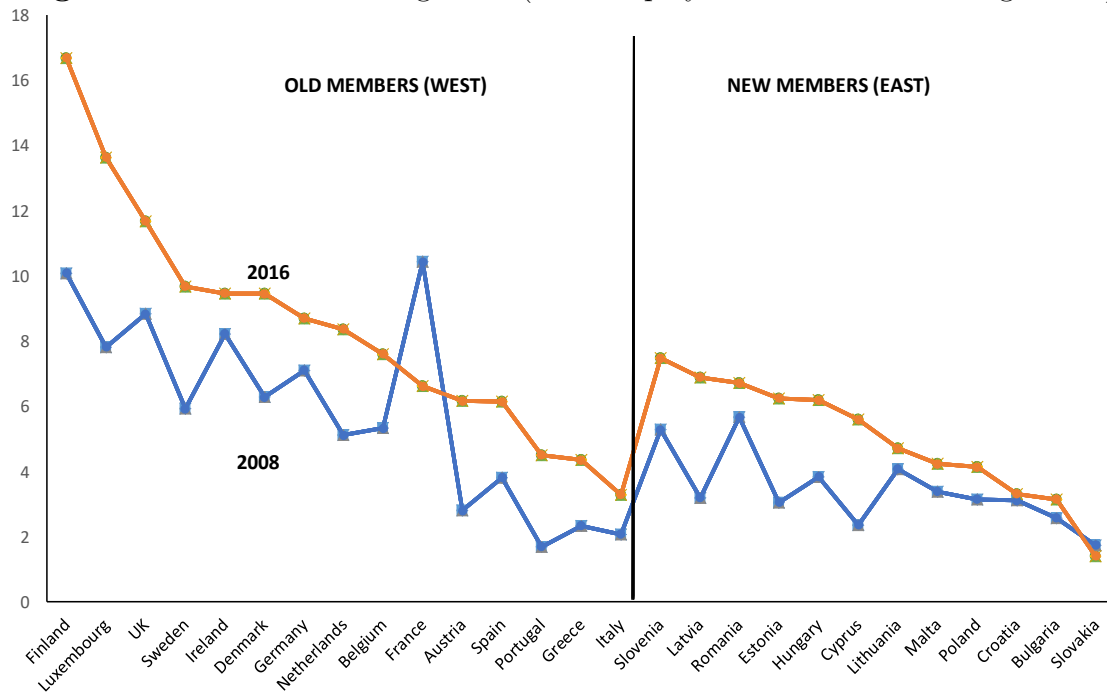
Source: Eurostat.

Governments can choose among various instruments to promote business R&D, either by providing direct support, such as grants, contracts, loans and subsidies, or through indirect support, such as tax allowances, credits, and accelerated depreciation of R&D capital expenditures. The absence of a common EU innovation policy translates in a strong heterogeneity in the public support for innovation. As an illustration, Figure 3 provides the direct and indirect (tax credit) government R&D support in 2012 as a percentage of the countries' GDP by the

⁴The old members are Germany, France, Italy, the Netherlands, Belgium, Luxembourg, Denmark, Ireland, United Kingdom, Greece, Spain, Portugal, Austria, Finland and Sweden. The new members are Czech Republic, Cyprus, Estonia, Latvia, Lithuania, Hungary, Malta, Poland, Slovenia and Slovakia that joined in 2004, Romania and Bulgaria, joined in 2007 and Croatia in 2013.

⁵The average difference between East and West is smaller if we consider total R&D, which includes public investment. The West records an average of 2% while the East attains a 0.9%.

Figure 2: Scientists and Engineers (% of employment in manufacturing sector)



Source: Eurostat.

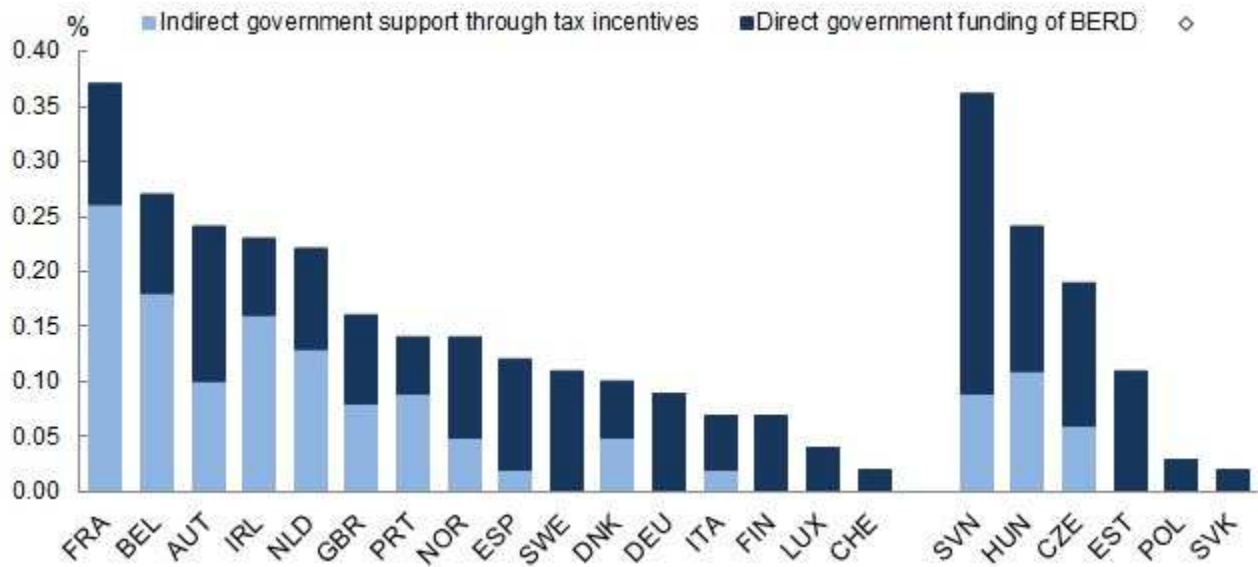
new and old member states' governments. France and Slovenia provide the most combined R&D funding for business as a percentage of GDP, with more than 0.35 percent of their GDP spent on R&D support. There are striking disparities in both direct and indirect (tax credit) support both for the old and the new member states. Of our sample of 22 countries, all the 16 western EU countries and the 6 new EU members received "direct" government support. In addition, 11 of the 16 old EU members and 3 of the 6 new EU members give "indirect" R&D support, such as tax credit. On average West EU governments provide direct support to R&D corresponding to about 0.08% of GDP and indirect support through the tax system of a similar amount. In the East, the direct support is larger (about 0.12% of GDP on average) and the indirect incentives amount to 0.03% of GDP.

This set of descriptive statistics deliver two clear messages. First, there is a large heterogeneity in innovation performances across EU countries with most of the activity concentrated in the Northern and old member countries. The amount of innovation performed in the new member countries is, though, substantial and growing. Second, the absence of a common EU innovation policy produces a strong heterogeneity in the public support for innovation.

2.2 Western multinationals and innovation in the East

Along with the increase in innovation, we observe a marked increase in inward FDI in the new member states. FDI stock as a share of total GDP of NMS doubles between 2001 and 2012. Over this period, the share of FDI stock in the NMS accounted for by the old members remains large

Figure 3: Direct government funding and Indirect government support through tax incentives, 2012



BERD: business enterprise expenditure on R&D. Source: OECD R&D Tax Incentives Indicators.

and stable around 80% (Eurostat). We dig deeper into the potential relationship between FDI and innovation analysing the empirical link between the presence of multinational affiliates and the local innovation activity of domestic firms. To this end, we rely on the Business Environment and Enterprise Performance Survey (BEEPS) which provides self-reported information from top managers on various types of innovation activity. This firm-level survey based on face-to-face interviews with managers realised during the years 2011-2014, includes 15,694 firms located in Eastern and Central European countries, as well as Russia and Turkey. For those years, the data provide information on the 2-digit sector classification, the exact regional location as well as the ownership of each firm.

An additional key feature of the BEEPS survey is that it includes several questions on product and process innovation. Firms report the introduction of the following innovation in the last 3 years: i) New products or services ii) New production or supply methods iii) New organisational, management practices or structures iv) New marketing methods. Based on this information, we identify domestic firms which report at least one of these new product or process innovations in a given year.⁶ This direct firm-level measure of innovation has previously been used by Gorodnichenko et al. (2010) and Gorodnichenko et al. (2015).⁷

⁶As the BEEPS survey only reports the number of firms reporting at least one new product or innovation over a 3 year period, we use the binomial distribution formula to recover the probability for a firm to report one additional product in a given year.

⁷While most studies on innovation use patent data or R&D expenditures, these authors argue that these measures are potentially problematic. Patents are likely to capture inventions rather than innovations, while

Aggregate results. We make use of this information to aggregate the data at the region-sector level and calculate both the share of domestic firms conducting innovation as well as the fraction of firms with foreign capital.⁸ We furthermore exclude all region-sector pair with fewer than 10 active firms.⁹ Using two-way clustering, we report robust standard error clustered both at the regional and at the sector level. We regress the share of domestically-owned firms reporting innovations on the share of firms with foreign capital in Table 1. We do that without any additional control in column 1. We then introduce region fixed-effects in column 2 and sector fixed-effects in column 3. In all regressions, we find a positive and significant relationship at the 1% level between the share of domestically-owned firms reporting innovations and the share of foreign affiliates. The positive relationship is also robust to the inclusion of both set of fixed-effects simultaneously, as in column 4. While the size of the coefficient largely decreases, it remains significant at the 1% level. Raising the share of foreign affiliates from the 25th to the 75th percentile (that is from 0 to 0.083) is associated with a predicted change in the share of domestic firms reporting innovation by 3.3 percentage points.

Table 1: Aggregate results: Share of Domestic firms reporting innovation and share of foreign firms at the region-sector level

Dependent variable:				
Share of domestic firms reporting innovation at the region-sector level				
	(1)	(2)	(3)	(4)
Share of foreign affiliates	0.701*** (0.133)	0.422*** (0.124)	0.660*** (0.127)	0.401*** (0.120)
region fixed-effects	No	Yes	No	Yes
Sector fixed-effects	No	No	Yes	Yes
Observations	346	346	346	346
R-squared	0.140	0.817	0.169	0.835

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.

Firm-level results. We then turn to a firm-level linear-probability model. Focusing on domestic firms, we construct our dependent variable as a dummy variable taking a value one if the firm reports product or process innovations, and zero otherwise. We then construct our main explanatory variable in two different ways: as a dummy variable indicating the presence or not of a foreign firm within the same region and within the same 2-digit sector than the firm, or

R&D does not necessarily lead to innovation.

⁸We consider as a foreign affiliate a firm with at least 50 percent of the capital owned by a foreign entrepreneur/company.

⁹Increasing the threshold to 20 or 30 active firms would decrease the number of observations but leads to qualitatively similar results.

as the *count* of foreign firms within the same sector-location. Table 2 reports our main results where all estimations include region, sector and year fixed effects. Regressions (2) and (4) also include additional firm-level controls: firms’ log of sales and a set of dummy variables for state-owned enterprises, exporting and importing status. The coefficient associated with ‘foreign presence’ is significant at least at the 5% level in all the estimations. Considering Column (2), a foreign presence in a region-sector is associated with an increase by 3.5 percentage points of the predicted probability for a domestic firm to report innovation.¹⁰ In the appendix, we also split the sample in many different ways and, as reported in Table A.1, we find more pronounced effects in manufacturing sectors than in services, and for private firms compared to state-owned enterprises. Effects also appear independent of the export and import status of the firm and persistent both for small and large firms (below or above the median size).

Table 2: Firm-level evidence: Domestic firms reporting innovation and foreign presence

Dependent variable:				
Firm-level dummy variable for domestic firms reporting innovation				
Explanatory variable:	dummy	dummy	count	count
	(1)	(2)	(3)	(4)
Foreign presence	0.034** (0.014)	0.035*** (0.013)	0.014*** (0.003)	0.012*** (0.003)
Control variables	No	Yes	No	Yes
Observations	14,877	11,466	14,877	11,466
R-squared	0.167	0.209	0.168	0.209

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.

While the literature on technology transfer recognises that FDI may act as a vehicle of technological transfer and may facilitate innovation in receiving countries, our suggestive evidence do not imply causation. Nevertheless, our results highlight the geographic clustering of domestic innovative firms in sectors with active foreign affiliates. Our findings complement those obtained by Gorodnichenko et al. (2010) and Gorodnichenko et al. (2015) using similar data for the same set of countries, but for different period of time.¹¹ While they use firm-level sales to multinational affiliates to identify vertical linkages between domestic firms and foreign

¹⁰Furthermore excluding all region-sector pair with fewer than 10 or 20 active firms as in the aggregate estimations would generate qualitatively similar results with similar sizable effects.

¹¹The information on the exact region of location of firms is only available for the years 2011-2014. Unfortunately, the information on the firm-level sales to multinational firms used by Gorodnichenko et al. (2010) and Gorodnichenko et al. (2015) is not available for those years.

affiliates, we use a more general definition capturing the presence of foreign affiliates within the same region-sector.

3 The Model

We consider an economy consisting of two regions: the old members (the West) including the developed high-wage economies, and the new members (the East) which consists of new lower-wage EU member countries. Labor in the West is employed in two types of activities: manufacturing of goods and innovative R&D which results in a quality upgrade of the goods. The West can hire labor in the East to conduct adaptive R&D in order to transfer production to the low-wage East. We call those firms western multinational enterprise subsidiaries, or the MNEs. The adaptive R&D spending can be regarded as FDI that facilitate technology and production transfer. Even when financed by eastern savings, as in our main specification, its intensity is still decided by the West and a fraction of the subsidiaries' higher global profits get repatriated back to the consumers in the West in the form of royalties.

While the West is capable of conducting innovation in all sectors of the economy, the East faces technological constraints and is able to innovate only in those sectors where previous western FDI has occurred. We view this feature of the model as a way to represent the importance of FDI knowledge spillovers which facilitate learning and the innovative activity of the East. Once a successful quality innovation in the East has occurred, the East takes over the global leadership in the sector until leapfrogged again by the western innovators. Trade between the two regions is free and the product cycle within a sector occurs in three stages: first through western FDI in the East, then by the eastern upgrade of the product quality to obtain the sectoral leadership, and finally through leapfrogging of the West which returns the sector's production to the West.

3.1 Households

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

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

subject to

$$\begin{aligned}
u(t) &\equiv \left(\int_0^1 \left[\sum_{j=0}^{j^{\max}(\omega,t)} \lambda^{j(\omega,t)} d(j, \omega, t) \right]^{\frac{\sigma-1}{\sigma}} d\omega \right)^{\frac{\sigma}{\sigma-1}} \\
c(t) &\equiv \int_0^1 \left[\sum_{j=0}^{j^{\max}(\omega,t)} p(j, \omega, t) d(j, \omega, t) \right] d\omega \\
W(0) + Z(0) - \int_0^\infty L_0 e^{-\int_0^t (r(s)-n) ds} \tau dt &= \int_0^\infty L_0 e^{-\int_0^t (r(s)-n) ds} c(t) dt,
\end{aligned}$$

where L_0 is the initial population and n is its constant growth rate, ρ is the common rate of time preference - with $\rho > n$ - and $r(t)$ is the market interest rate on a risk-free bond available in both regions. $d(j, \omega, t)$ is the per-member flow of goods in sector ω , each good of quality level $j \in \{0, 1, 2, \dots\}$, purchased by a household at time $t \geq 0$. $p(j, \omega, t)$ is the price of a good of quality level j in sector ω at time t , $c(t)$ is nominal expenditure, and $W(0)$ and $Z(0)$ are human and non-human wealth levels. 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. Finally, τ is a per-capita lump-sum tax.

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 linez 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:

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

where $q(\omega, t) = \lambda^{j(\omega,t)(\sigma-1)}$ is a measure of the good's quality and $P(t) = \left[\int_0^1 q(\omega, t) p(\omega, t)^{1-\sigma} d\omega \right]^{\frac{1}{1-\sigma}}$ is the quality-price index. The presence of a lump sum tax does not change the standard solution of the intertemporal maximization problem, which leads to the standard Euler equation,

$$\frac{\dot{c}}{c} = r(t) - \rho. \quad (3)$$

We focus on the analysis of the steady state equilibrium where per capita expenditure c is constant and therefore $r(t) = r = \rho$.

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 labor requirement a^k , where $k = W, E, M$ is the producer indicator for the West, the East and the western multinational subsidiary respectively. The wage rate in the two regions is w^K , $K = W, E$. In each industry the top quality product can be manufactured only by the firm that has discovered it, as patent rights are protected by a perfectly enforceable world-wide patent law. As is usual in Schumpeterian models with vertical innovation (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.

Assumption 1. *Trade is free in the economic union.*

Since our quantitative application will be to the EU, it is natural to assume away any tariffs, export subsidies or other political barriers to trade. Our analysis focuses on R&D subsidies and FDI costs/barriers so we also assume away any other form of trade costs.¹² We restrict our attention to the steady state equilibria where the following conditions are satisfied: $w^E > \frac{a^W w^W}{a^E \lambda}$, $w^E > \frac{a^W w^W}{a^M \lambda}$ and $\lambda > \frac{a^E}{a^M}$. These conditions guarantee the existence of a complete product cycle. The first condition states that the innovation quality improvement is large enough for a western quality leader producing in the West to have a lower quality-adjusted production cost than an eastern firm producing in the east one step below on the quality ladder. If wages are lower in the East this condition suggests the western quality leader can drive the lower cost competitor out of the market. Similarly the second condition posits that a western quality leader can outcompete a foreign affiliate producing a quality inferior good at a lower unit cost. The third condition states that the quality jump is large enough to allow the eastern innovator to leapfrog the western multinational.

We follow the common practice and assume that to participate in pricing competition, in each product line, firms must pay a small fee (e.g. Howitt, 1999, Dinopoulos and Segerstrom, 2010). Under this assumption the profit maximising choice of the quality leader is always to charge the monopoly price:¹³

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

¹²Other, non policy-related, trade costs could be easily added but are not key for the questions we focus on.

¹³Typically in these models the quality leader can charge the monopoly price when the innovation is 'drastic', which implies a large λ , or 'non-drastic', when λ is low. 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.

Substituting (4) for the price in the static consumer demand (2), and using it to express the monopoly profits accruing to global quality leaders from region $K = W, E$ in sector ω , we obtain

$$\pi^K(\omega, t) = \frac{1}{\sigma} \left(\frac{\sigma}{\sigma - 1} \right)^{1-\sigma} (a^K w^K(t))^{1-\sigma} q(\omega, t) \frac{c(t)L(t)}{P(t)^{1-\sigma}}, \quad (5)$$

where $c(t) = c^W(t)\ell^W + c^E(t)(1 - \ell^W)$ and $\ell^W = L^W(t)/(L^W(t) + L^E(t)) = L^W(t)/L(t)$ is the share of total labor force in region W . For MNE's subsidiary firms that produce in the East, the profits are given by

$$\pi^M(\omega, t) = \frac{1}{\sigma} \left(\frac{\sigma}{\sigma - 1} \right)^{1-\sigma} (a^M w^E(t))^{1-\sigma} q(\omega, t) \frac{c(t)L(t)}{P(t)^{1-\sigma}}. \quad (6)$$

We choose the western wage to be the numeraire of our economy, $w^W = 1$.

3.3 Global R&D races

In each sector, leaders are challenged by R&D firms that employ workers and produce a probability intensity of inventing the next version of their products. Before the establishment of subsidiary firms in the East, only western firms are capable of performing R&D and challenging western leaders across sectors. However, once a subsidiary initiates adaptive R&D and transfers production to the East, technology transfer makes possible for R&D activities to take place in the East as well. This assumption is summarised below.

Assumption 2. *Western firms innovate in all sectors, East innovates only in those sectors that experienced Western FDI.*

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 R&D firms targeting product ω . Each R&D firm can produce a Poisson arrival rate of innovation according to the following technology:

$$I_i^k(\omega, t) = \frac{A^k(\omega, t)l_i^k(\omega, t)}{X(\omega, t)}, \quad (7)$$

where $A^k(\omega, t)$ and $X(\omega, t) > 0$ measures the degree of complexity in the invention of the next quality product in industry ω , $L^k(\omega, t) = \sum_i l_i^k(\omega, t)$ is the total labor used for R&D and $I^k(\omega, t) = \sum_i I_i^k(\omega, t)$ is the total investment in R&D (total arrival rate) by k -type sector firms. $A^k(\omega, t)$ is the R&D productivity parameter which is region and sector specific. It is a function of the exogenous R&D labor productivity parameter, γ^k , and the sector's relative quality level, $\frac{q(\omega, t)}{Q(t)}$, where $Q(t)$ is the average quality in the economy defined as $Q(t) = \int_0^1 q(\omega, t)d\omega$. We assume that A^k is a decreasing function of the relative quality: the higher the complexity of the sector's product relative to the average quality of the economy, the harder it is to improve

on the product's quality. In the East, we assume that the R&D productivity, $A^E(\omega, t)$, is a function of the ω -sector's product quality relative to the average quality in the region, i.e. $Q^{E+M}(t)$ defined as $Q^{E+M}(t) = \int_{\omega^E + \omega^M} q(\omega, t) d\omega$, where ω^E and ω^M are the share of sectors where the quality leader is an eastern firm and a western multinational respectively. We also define $\omega^W = 1 - \omega^E - \omega^M$ as the industry share with western firms leadership.¹⁴ We summarise this assumption below.

Assumption 3 (Localised knowledge spillovers). *The sector and type-specific R&D productivity parameters are,*

$$\begin{aligned} A^W(\omega, t) &= \gamma^W \left(\frac{q(\omega, t)}{Q(t)} \right)^{-1} \quad \text{for } \omega \in \omega^W, \\ A^M(\omega, t) &= \gamma^M \left(\frac{q(\omega, t)}{Q(t)} \right)^{-1} \quad \text{for } \omega \in \omega^M, \\ A^E(\omega, t) &= \gamma^E \left(\frac{q(\omega, t)}{Q^{E+M}(t)} \right)^{-1} \quad \text{for } \omega \in \omega^E. \end{aligned} \quad (8)$$

The technological complexity index $X(\omega, t)$ is introduced to eliminate scale effects. We use the following specification:

$$X(\omega, t) = 2\kappa L(t), \quad (9)$$

with a positive constant κ and $N(t)$ as the total population size, thereby formalising the idea that it is harder to innovate in a more crowded market (Dinopoulos and Thompson, 1998). This specification leads to a class of models known as 'fully-endogenous growth frameworks' in which policy affects the long-run growth of the economy.¹⁵

Governments subsidise R&D expenditures at the rate s^K , which is region-specific but uniform across sectors. FDI is a particular type of R&D that is used to transfer the technology abroad and contributes to innovation and growth only indirectly by allowing foreign firms to innovate in a larger set of sectors. Hence, in our benchmark specification we make the sensible assumption that FDI benefits from the same subsidy as normal R&D.¹⁶ Each firm chooses the amount of labor devoted to R&D, l_i^k , in order to maximise its expected discounted profits. Free entry into R&D races drives the expected profits to zero, generating the following equilibrium condition:

$$v^k(\omega, t) \frac{A^k(\omega, t)}{X(t)} = (1 - s^K)w^K, \quad (10)$$

¹⁴This is consistent with the empirical evidence on the local nature of technological spillovers (Audretsch and Feldman, 2003, Gorodnichenko et al. (2015)).

¹⁵The key results of the paper hold also in a semi-endogenous version of the model, where policy has only transitional effects on growth (e.g. Jones, 1995, and Segerstrom, 1998), but the decomposition of the static and dynamic gains is hardly possible without solving for the transitional dynamics.

¹⁶We later remove this assumption and treat the FDI and R&D subsidies as different policy tools.

where $v^k(\omega, t)$ is the present value of a firm that produces in sector $k = W, E, M$. The presence of efficient financial markets implies that the expected rate of return of a stock issued by an R&D firm is equal to the riskless rate of return $r(t)$. It follows that the expected value of a firm is:

$$v^k(\omega, t) = \frac{\pi^k(\omega, t)}{r(t) + I^k(\omega, t) - \frac{\dot{v}(\omega, t)}{v(\omega, t)}}, \quad (11)$$

where $I^k(\omega, t)$ denotes the sectoral Poisson arrival rate of innovation that will destroy the incumbent monopolist's profits in sector ω . This is Schumpeterian *creative destruction*: successful innovation of some firms comes at the expense of other firms. In the absence of any cost advantage in R&D for incumbent firms, the usual Arrow effect (Aghion and Howitt, 1992) implies that they do not find it profitable to innovate, and innovation is performed only by entrants. Substituting for the value of the firm from (11) into (10) we obtain:

$$\frac{\pi^k(\omega, t)}{r(t) + I^k(\omega, t) - \frac{\dot{v}(\omega, t)}{v(\omega, t)}} = \frac{(1 - s^K)w^K X(t)}{A^k(\omega, t)} \quad \text{for } \kappa = W, E, M. \quad (12)$$

This condition, together with the Euler equation summarises the utility maximising household choice of consumption and savings, and the profit maximising choice of production and innovation.

3.4 Balanced growth

Next, we derive the steady-state properties, where per-capita endogenous variables are stationary. Moreover, to complete the characterisation of the model we need the labor market clearing conditions and the national expenditure constraints.

With constant wages, it follows from the free entry condition (10) that $\dot{v}^k(t)/v^k(t) = \dot{X}(t)/X(t) - \dot{A}^k(t)/A^k(t) = n - g$, for $k = W, E, M$, with g as the growth rate of the average quality $Q(t)$. We analyze a steady state with constant c^K and w^K , so that $r(t) = \rho$ follows from the Euler equation for consumption. The common quality-price index is given by

$$P(t) = \bar{P}Q(t)^{\frac{1}{1-\sigma}}, \quad (13)$$

where $\bar{P} = [q^W p^{W(1-\sigma)} + q^M p^{M(1-\sigma)} + q^E p^{E(1-\sigma)}]^{\frac{1}{1-\sigma}}$ is the contribution of western quality leaders, western affiliates and eastern quality leaders to the price index. The relative qualities $q^j = Q^j(t)/Q(t)$ are constant in steady state as shown later, hence \bar{P} is constant. Substituting for profits into (12), we determine the equilibrium innovation condition in three different types of sectors (firms) as

$$\frac{(1 - s^W)2\kappa}{\gamma^W} = \frac{a^{W(1-\sigma)}\sigma^{-\sigma}}{[\bar{P}(\sigma-1)]^{(1-\sigma)}C} \quad \text{for } \omega \in \omega^W, \quad (14)$$

$$\frac{(1 - s^E)2\kappa w^E}{\gamma^E} = \frac{(q^E + q^M)^{\sigma - \sigma} a^{E(1-\sigma)} w^{E(1-\sigma)} c}{[\bar{P}(\sigma - 1)]^{(1-\sigma)} \rho + I^W + I^E - n + g} \quad \text{for } \omega \in \omega^E, \quad (15)$$

$$\frac{(1 - s^E)2\kappa w^E}{\gamma^M} = \frac{c\sigma^{-\sigma}}{[\bar{P}(\sigma - 1)]^{(1-\sigma)}} \left(\frac{a^{M(1-\sigma)} w^{E(1-\sigma)}}{\rho + I^W + I^E - n + g} - \frac{a^{W(1-\sigma)}}{\rho + I^W - n + g} \right) \quad \text{for } \omega \in \omega^M. \quad (16)$$

Equation (14) shows that the benefits of innovation in industries with western quality leaders, $\omega \in \omega^W$, are determined by profits and the rate of Schumpeterian ‘creative destruction’ in those industries: the higher the innovation in the sector, I^W , the lower the duration of a patent, hence the lower is the expected value of a firm. The costs are determined by the labor costs and by R&D subsidies. Similarly, (15) shows the costs and benefits of innovation in sectors with eastern leaders, $\omega \in \omega^E$. In those sectors firms from both regions are engaged in R&D, which also implies that by affecting national firms’ innovation, western R&D subsidies can have a direct negative effect on eastern firms’ innovation. The equilibrium conditions for establishing MNE’s subsidiary firms in the East are shown in (16). The adaptive R&D cost is equal to the benefit of these establishments accruing to the western headquarter, given by the difference between the value of a western quality leader producing in the East, v^M , and its value producing in the West, v^W . The key endogenous variables affecting the benefit of the transfer are the difference in labor cost between the two locations, the *wage gap* and the difference in innovation determined by I^W and I^E , the *creative destruction gap*. Higher innovation in the East reduces the creative destruction gap which implies an increase in the risk of being copied and technologically leapfrogged for western firms and therefore a lower incentive to offshore production.

In order to obtain an invariant industry composition, the growth rates of average quality Q and its components (Q^W , Q^E and Q^M) must be equal and constant in steady state, which yields the following set of equilibrium conditions as derived in Appendix B,

$$\lambda^{\sigma-1} I^W (q^W)^{-1} = I^M (q^M + q^E)^{-1} + (\lambda^{\sigma-1} - 1) I^E, \quad (17)$$

$$\frac{q^W}{q^M + q^E} = \lambda^{\sigma-1} \frac{I^E q^M}{I^M q^E}, \quad (18)$$

where $q^W + q^E + q^M = 1$. Average quality $Q(t)$ evolves due to innovation performed in the West and the East,

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

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 , which takes place in all sectors of the economy, and innovation by eastern leaders I^E taking place in the subset of sectors where the leaders are multinationals or eastern firms ($\omega^M + \omega^E$)¹⁷. Adaptive R&D affects growth only indirectly via the share of sectors where the East innovates, $1 - q^W$. As we will show later, the growth rate of the average quality pins down the growth rate of the global economy g .

Finally, we characterise the labor market clearing conditions. Labor demand in the West comes from production in the sectors with production in the West, ω^W , and R&D activities in all sectors. Workers in the East are employed in production activities by western MNE's subsidiaries in ω^M sectors and by eastern firms in sectors ω^E . Labor 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 with production in the East, ω^M and ω^E . The labor market conditions are then,

$$\ell^W = \left(\frac{\sigma}{\sigma - 1} \right)^{-\sigma} a^{W(1-\sigma)} \frac{cq^W}{\bar{P}^{1-\sigma}} + \frac{I^W 2\kappa}{\gamma^W}, \quad (20)$$

in the West, and in the East,

$$\begin{aligned} 1 - \ell^W &= \left(\frac{\sigma}{\sigma - 1} \right)^{-\sigma} a^{M(1-\sigma)} w^{E(-\sigma)} \frac{cq^M}{\bar{P}^{1-\sigma}} + \left(\frac{\sigma}{\sigma - 1} \right)^{-\sigma} a^{E(1-\sigma)} w^{E(-\sigma)} \frac{cq^E}{\bar{P}^{1-\sigma}} \\ &+ \frac{I^M 2\kappa}{\gamma^M} q^W + \frac{I^E 2\kappa}{\gamma^E}. \end{aligned} \quad (21)$$

Equations (14), (15), (16), (17)-(18), (19), (20) and (21) define a set of equilibrium conditions for endogenous variables c , I^W , I^E , I^M , w^E , g , q^W and q^E .

Sectoral composition. In steady state the shares of the three types of sectors in the economy, those with western leaders and production in the West, those with western leaders but offshored production to the East, and those with leadership and production in the East, must be constant. Hence, the outflows and the inflows into each type have to be equalised. Formally, 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 the share of western sectors as a function of the innovation and technology transfer rates

$$\omega^W = \frac{I^W}{I^M + I^W}. \quad (22)$$

¹⁷Notice that, by definition, relative qualities q 's follow relative shares ω 's.

Similarly, in the East, the condition for the sectors with eastern leadership is given by $\omega^E I^W = \omega^M I^E$, which, using (22) and $\omega^W + \omega^M + \omega^E = 1$, gives

$$\omega^E = \frac{I^M}{I^M + I^W} \frac{I^E}{I^E + I^W}. \quad (23)$$

Finally, the share of sectors with production by multinationals is given by

$$\omega^M = \frac{I^M}{I^M + I^W} \frac{I^W}{I^E + I^W}. \quad (24)$$

Consumption and welfare. Next, we derive the steady-state consumer expenditures and welfares in the two regions. The intertemporal budget constraint of a western consumer is represented by $\dot{\mathcal{A}}^W(t) = w^W + \rho \mathcal{A}^W(t) - c^W - n \mathcal{A}^W(t) - \tau^W$, where $\mathcal{A}^W(t)$ denotes the total asset per capita, and τ^W is the lump-sum tax that is used to finance the R&D subsidies. Dividing this expression by $\mathcal{A}^W(t)$ and noting that $\dot{\mathcal{A}}^W(t)/\mathcal{A}^W(t)$ must be constant in a steady-state equilibrium, it follows that $\mathcal{A}^W(t)$ must also be constant. This gives the western per-capita consumer expenditure as

$$c^W = 1 + (\rho - n) \mathcal{A}^W - \tau^W, \quad (25)$$

and total stock of per capita assets is given by the total value of western firms

$$\mathcal{A}^W = \int_{\omega^W + \omega^M} \frac{v^W(\omega)}{L^W(t)} d\omega = (1 - s^W) \frac{2\kappa}{\gamma^W \ell^W} (q^W + q^M), \quad (26)$$

where we have used the free entry condition (12) to express the value of the firm in terms of the innovation cost. Total western assets are given by the value (discounted stream of profits) of all businesses whose creation is financed by the western consumers. In this benchmark specification we assume that western households finance the innovative R&D in the West and thus receive, in the form of dividends, the profits of firms operating in the West. We also assume that East households finance adaptive R&D (FDI), but a part of the profits of multinational firms are repatriated to the West as royalties.

Assumption 4. *West households receive a share of the profits of foreign affiliates, as royalties for their technology. East households receive the remaining profits.*

In the East, the total per-capita consumer expenditure is

$$c^E = w^E + (\rho - n) \mathcal{A}^E - \tau^E, \quad (27)$$

where τ^E denotes the lump-sum tax used to finance the R&D subsidies of eastern firms and

the adaptive R&D of the multinationals, and

$$\begin{aligned} \mathcal{A}^E &= \int_{\omega^E} \frac{v^E(\omega)}{L^E} d\omega + \int_{\omega^M} \frac{v^M(\omega) - v^W(\omega)}{L^E} d\omega \\ &= (1 - s^E) w^E \frac{2\kappa}{\ell^E} \left(\frac{q^E}{\gamma^E (q^E + q^M)} + \frac{q^M}{\gamma^M} \right), \end{aligned} \quad (28)$$

is the value of firms in the East, which comes from production transfer to the East and from eastern firms' market leadership. Once the transfer occurs, eastern firms receive the surplus profits, the difference between the higher profits and the royalties paid out to the West.¹⁸ Moreover, eastern consumers finance the innovative R&D of the local firms and thus receive the profits of eastern leaders.

We complete the description of the model by showing the expressions for per-capita welfare, the balanced growth path utility in each region which is given by

$$u^K(t) = \frac{c^K}{P(t)}, \quad (29)$$

stating that in each period welfare is pinned down by real consumption. The common quality-price index $P(t) = \bar{P}Q(t)^{\frac{1}{1-\sigma}}$ is defined in (13). Recall that \bar{P} measures the contribution of western quality leaders, western affiliates and eastern quality leaders to the price index. Since prices in (4) are a function of wages, \bar{P} increases with the wage in the East, and for a given w^E , since $w^E < 1$ it increases when the share of industries with western leadership expands. When production is more concentrated in the region with high labor cost, for a given quality, goods are more expensive. Aggregate quality at time t is pinned down by the total number of innovations from time zero to t , $Q(t) = Q(0)e^{gt}$, where by assumption the initial quality level is 1, $Q(0) = 1$. Utility grows due to falling quality-price index with quality improvements. The growth rate of utility is

$$\frac{\dot{u}(t)}{u(t)} = \frac{1}{\sigma - 1} \frac{\dot{Q}(t)}{Q(t)} = \frac{g}{\sigma - 1}. \quad (30)$$

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

¹⁸We have used conditions (16)-(15) to express the value of eastern firms in terms of the cost of the innovation activity performed in the East. An alternative specification may consider a different assets allocation where the West finances adaptive R&D and thus appropriates the total increased profits from the multinationals operation in the East. We present this specification in Appendix C.1.

state welfare and can be written as

$$\begin{aligned}
U^K &= \int_0^\infty N_0 e^{-(\rho-n)t} (\log c^K(t) - \log P(t)) dt \\
&= \frac{\log c^K}{\rho - n} - \frac{\log \bar{P}}{\rho - n} + \frac{g}{(\sigma - 1)(\rho - n)^2}.
\end{aligned} \tag{31}$$

Policy affects welfare through a *static* channel, working through the per-capital nominal consumption level c^K and the impact of the geographical leadership distribution on the price index \bar{P} ; and a *dynamic* channel operating through the effect of quality growth g on the price index.

Key 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. As in the standard Schumpeterian growth model, 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 Aghion and Howitt (1992) term an *intertemporal 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. In our utility metric (29), they operate through the price index $P(t)$ and they are usually hard to separate.¹⁹ Isolating these two effects can be important. The consumer surplus effect is not specific to endogenous growth theory, it is also present in any static where innovation reduces the price of the good it targets with no future effects.²⁰ The intertemporal spillover effect is the new key feature brought about by endogenous growth theory. Heuristically, we separate the two externalities, positing that the *consumer surplus effect* (*CSE* henceforth) operates via the non-growing component of the price index \bar{P} , and the intertemporal spillover effect, which for simplicity we call *growth effect* (*GRE* henceforth), operates in our utility metric via the growth rate of quality.

The other classic external effect of innovation in this class of models is the *business-stealing effect* (*BSE* henceforth) 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

¹⁹In standard versions of the closed-economy Schumpeterian model Grossman and Helpman (1991a) and Segerstrom (1998) derive analytical expressions for all the external effects of innovation, but cannot separate the consumer surplus and the intertemporal spillover.

²⁰For instance, this is present in static models of strategic trade and industrial policy (e.g. Eaton and Grossman, 1986, Leahy and Neary, 1997, 2009).

consumption. This reduction in consumption lowers the profits of the other leading firms. The innovating firm does not take this into account and is therefore bound to overinvest in R&D. This, therefore, is a motive for taxing innovation.

The open economy dimensions add new motives for subsidies. The asymmetric nature of our economy demands a separate explanation for the two regions. We start with the West. In sectors where the market leader is an eastern firm, successful western innovation drives the incumbent firm out of business and shifts monopolistic profits and wages toward the West, thereby increasing domestic welfare. This is the standard *strategic motive* for subsidies (e.g. Spencer and Brander, 1983, Eaton and Grossman, 1986). This is another version of the business-stealing effect, where the profits obtained by the successful western innovator have a positive multiplier effect on the profits of the other western firms via higher consumption. The possibility of offshoring production adds other layers to this effect. Stronger innovation in the West reduces the incentive to innovate in the East, due to higher creative destruction, as suggested by (15). Lower innovation in the East makes production transfer by the multinationals more profitable, as the threat of being copied and leapfrogged by eastern firms declines.²¹ More FDI shifts labor demand and partially profits to the East thereby triggering an adverse profit and wage-shifting effect which, via a reduction of aggregate consumption, has a negative effect on all western firms. Hence, the presence of multinational firms tames the strategic motive for subsidy. We label these strategic effects produced by R&D subsidies *international business-stealing effect (IBSE)*.²²

In the East, the *IBSE* works similarly as in the West but with an extra twist. Successful eastern innovation in product lines with a western leader drives this incumbent firm out of business and shifts their business toward the East. This business-shifting role constitutes a motive for eastern governments to subsidise R&D. FDI complicates matters again. First, in our benchmark economy the same R&D subsidy is applied to innovation and FDI (adaptive R&D), thus East R&D subsidies reduce the cost of FDI, thereby encouraging more production transfer. However, higher eastern innovation also implies higher threat for western firms of being leapfrogged if they move production abroad. This stronger threat of creative destruction abroad can offset the lower cost of moving production to the East generated by higher R&D subsidies, thereby reducing the incentives for FDI. With less FDI, wages, profits and consumption in the East decline and with them the strategic motive to subsidise R&D weakens. Hence, the *IBSE* of eastern innovation has, in principle, an ambiguous impact on eastern welfare and therefore on the desirability of R&D subsidies. Moreover, the possible reduction in the share of sectors where eastern firms innovate, due to the reduction in FDI, could potentially have a negative impact on growth, which is not considered by eastern innovators and, consequently, the growth

²¹These effects are shown later, in Figure 4.

²²Versions of this strategic role of R&D subsidies in open economies Schumpeterian growth models without multinational corporations can be found in Impullitti (2010), and Akcigit et al. (2018).

motive for subsidy in the East is also ambiguous.²³ Finally, the static consumer surplus effect operates as in the West, thereby justifying positive R&D subsidies.

R&D subsidies encourage innovation and affect welfare via these channels. To sum up, we can use our utility metric (31) and express heuristically the different marginal effects of R&D subsidies on welfare as,

$$\frac{\partial W^W}{\partial s^W} = \underbrace{\frac{\partial \tilde{c}^W}{\partial s^W}}_{BSE} + \underbrace{\frac{\partial \tilde{c}^W}{\partial s^W}}_{IBSE} + \underbrace{\frac{\partial \tilde{P}}{\partial s^W}}_{CSE} + \underbrace{\frac{\partial \tilde{g}}{\partial s^W}}_{GRE}, \quad (32)$$

$(-)$ $(+/-)$ $(+)$ $(+)$

for the West and

$$\frac{\partial W^E}{\partial s^E} = \underbrace{\frac{\partial \tilde{c}^E}{\partial s^E}}_{BSE} + \underbrace{\frac{\partial \tilde{c}^E}{\partial s^E}}_{IBSE} + \underbrace{\frac{\partial \tilde{P}}{\partial s^E}}_{CSE} + \underbrace{\frac{\partial \tilde{g}}{\partial s^E}}_{GRE}, \quad (33)$$

$(-)$ $(+/-)$ $(+)$ $(+/-)$

for the East. Where $\partial \tilde{c}^W / \partial s^W$ indicates that the mechanism operates through expenditures c^W , from (31), $\tilde{c}^W = \ln(c^W) / (\rho - n)$. The consumer surplus effect operates on the static constant component of the price index, $\tilde{P} = \ln(\bar{P}) / (\rho - n)$, and $\partial \tilde{g} / \partial s^W$ is the dynamic channel operating through the varying component of the price index, the growth rate $\tilde{g} = g / ((\sigma - 1)(\rho - n)^2)$. The plus and minus signs signal that the external effect leads respectively to underinvestment, thereby motivating the R&D subsidies, or overinvestment, thereby motivating the R&D taxes.

Finally, it is worth noticing that the absence of any trade barriers in our economic union implies a common growth rate so that the growth effect of national subsidies spills over to all countries, impeding the *GRE* to play a strategic role.

4 Quantitative analysis

Next, we calibrate the model to the EU data and explore its key properties numerically. We first analyse the effects of each region's subsidies separately and then compare the welfare outcomes of two different policy environments: non-cooperative Nash equilibrium and a cooperative, unified, R&D subsidy.

²³We expand on this later, when we explore numerically the effect of changes in eastern subsidies (see footnote 29).

4.1 Model calibration

We calibrate the parameters of the model to match the long-run empirical regularities of the EU economy. There are 14 parameters. Four of them, ρ , σ , n , ℓ^W , and the two R&D subsidies, s^W and s^E , are assigned their values using data from Eurostat, OECD and some standard values from the growth and business cycle literatures. The production productivity parameter of the West, a^W and the constant κ in the the R&D difficulty index are normalized to 1. The remaining 6 parameters, γ^W , γ^M , γ^E , a^M , a^E (the production and R&D productivity parameters) and λ (the innovation step size), are calibrated internally in a way that best matches the model's steady state to empirical facts of the EU economy, i.e. the long-run averages for the old and the new EU member states.

Some parameters of the model have close counterparts in real economies so that their calibration is straightforward. We set ρ , which in the steady state is equal to the interest rate r , to 0.049 to match the average Maastricht Treaty EMU convergence criterion series related to the interest rates for long-term government bonds in the 2001-2013 period in the EU. We set σ to 4.5, to match an average markup over the marginal cost of 28.6 %. This is consistent with the range 19 – 35 % in selected European countries reported in the German Central Bank Montly Report (2017). Next, we select the value for n to match the population growth rate of 0.508%, which is the average EU population growth rate for a longer period, 1961-2013 (Eurostat). We use the initial values for the subsidies of the two regions of 15.6% and 14.2% for the West and the East, respectively, which are the average values of direct and indirect government support to R&D (through R&D tax credit) in 2011 in the two regions, obtained from the OECD, Main Science and Technology Indicators Database. Finally, we calculate the West relative labor force size (ℓ^W) of 0.802 from the Eurostat 2015 population data.

We then simultaneously choose γ^W , γ^M , γ^E , a^M , a^E and λ to match the following statistics. First, using data from Section 2, we target the West-East relative business sector R&D investment, as a share of GDP, of 1.86, and the average share of scientists and engineers in the total manufacturing employment, of 8.04% and 4.86% for the old and the new member states, respectively (Eurostat, 2015). The latter target is used as a measure of the R&D labor share. Such wider measure of the R&D labor as the personnel capable of performing innovation tasks of any type may better capture the labor involved in the adaptive R&D in the East as well. Third, we match the average multifactor productivity growth rate for the EU economy of 0.66% in 2016 (OECD, 2005-2016 average).

Finally, we target the shares of sectors with western and eastern leadership of 88.96% and 6.63%, respectively (Eurostat, 2015). Given the lack of firm ownership information, particularly for the countries in the East group, it is hard to find good data targets for the leadership shares. We target two statistics broadly related to the shares of leadership in the model, using data on

Table 3: Calibration summary

External parameters	Value	Source
Interest rate ($r = \rho$)	0.049	Eurostat, 2001-2013
Utility f-n parameter (σ)	4.5	Bundesbank, 2017
Population growth rate (n)	0.508%	Eurostat, 1961-2013
R&D subsidy, West (s^W)	15.6%	OECD, 2011
R&D subsidy, East (s^E)	14.2%	OECD, 2011
Relative labor size, West (l^W)	0.802	Eurostat, 2015
Calibrated parameters	Value	
Innovative R&D productivity parameter, West (γ^W)	0.61	
Innovative R&D productivity parameter, East (γ^E)	2.56	
Adaptive R&D productivity parameter (γ^M)	1.30	
Manufacturing productivity, East (a^E)	1.91	
Manufacturing productivity, MNE's subsidiaries (a^M)	2.03	
Quality jump size (λ)	1.2	
Calibration targets	Data (Model)	Source
MFP growth rate	0.66% (0.51%)	OECD, 2005-2016
Share of sectors, Western leadership (ω^W)	88.96% (89.48%)	Eurostat, 2010
Share of sectors, Eastern leadership (ω^E)	6.63% (3.31%)	Eurostat, 2010
West-East relative R&D investment as a share of GDP	1.86% (1.40%)	Eurostat, 2015
Scientists and engineers labor share, West	8.04% (8.18%)	Eurostat, 2015
Scientists and engineers labor share, East	4.86% (5.31%)	Eurostat, 2015

GDP and Foreign Direct Investment (FDI) within-EU27 and external.²⁴ We proceed as follows: first, we exclude the external (non-EU) FDI stock in the EU27 area from the regions' and the area's total GDP. The share of EU15 GDP (excluding FDI from the EU12 to the EU15) in the total EU27 GDP represents the target for the share of sectors with western leadership, ω^W . The share of EU12 GDP (excluding EU15 FDI in the EU12) in the total EU27 GDP is used as a target for the share of sectors with East leadership, ω^E . Finally, we use the EU15 FDI stock in the EU12 as a share of the EU27 GDP to represent the share of sectors under the control of Western subsidiary firms in the East, ω^M . A more detailed description of this part of the calibration strategy can be found in Appendix (B.1). The parameters' values are obtained by minimising the quadratic distance between the model steady state and the statistics listed above. We summarize the calibration results in Table 3. Except for falling short of matching the share of sectors with eastern leadership, our stylised model performs fairly well in fitting the data targets.

4.2 Unilateral changes in R&D subsidies

We begin our analysis exploring the effects of R&D subsidies and their underlying mechanisms in each region. More precisely, we keep the R&D subsidy of a region constant at the benchmark value and describe the effects of changing the subsidy in the other region. The results are useful in understanding the outcomes of the policy games that we analyse later.

Subsidising R&D in the West. In the first experiment, we keep the R&D subsidy of a region constant at the benchmark value and describe the effects of changing the subsidy of the other region. Figure 4 shows the effects of changing the western subsidy in an interval of the benchmark value.²⁵ An increase in the western subsidy stimulates the sectoral level of innovation in the West, I^W , as it reduces the cost of innovation. Higher western innovation implies more creative destruction for eastern firms and therefore, successful innovators there expect a lower duration of their leadership; as can be seen in the free entry condition (15). As a consequence, the return to innovation in the East declines and with it the innovation rate I^E . Moreover, a higher western subsidy increases adaptive R&D investment and production transfer to the East, I^M . The free entry condition (16) suggests that the decision to transfer technology and production abroad is pinned down by the difference in labor cost and in creative destruction. For a given wage difference, a higher level of innovation in the West and a lower

²⁴EU27 stands for the European Union of the year 2007, i.e before the latest addition of Croatia as its member in 2013. It 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 EU12 (new members, the East) which includes Cyprus, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Slovakia, Slovenia, Bulgaria and Romania.

²⁵We choose an interval between a 5% and 25% subsidy which roughly represent the minimum and maximum government support due to tax incentives in Figure 3.

in the East implies that western firms face a lower risk of being leapfrogged by eastern firms when moving their production abroad. Hence, a higher western subsidy increases the incentive to transfer technology and production abroad.²⁶

The changes in innovation described above affect the geographical distribution of market leadership. The set of sectors with direct West leadership ω^W decreases, while the set with western multinational leadership ω^M increases. Interestingly, although adaptive innovation is performed by western firms in the East, and therefore does not benefit from western R&D subsidies, it experiences a stronger growth following an increase in s^W than western innovation: the former rises by about 60% while the latter rises by 25% when s^W rises from its benchmark of 15.6% to 25%. Thus, the general equilibrium effect of the subsidy through creative destruction is stronger than the direct effect via the reduction of innovation costs, and higher western subsidies lead to an expanded western leadership through multinational production. Notice also that the increase in technology and production transfer triggers an increase in labor demand in the East relative to the West, thereby leading to an increase in eastern relative wage.

Higher western subsidies trigger a higher global growth rate. This happens because the subsidy increases innovation per sector in the West, I^W , the region that innovates in all sectors of the economy, and reduces innovation per sector in the East, where firms only innovate in a subset of industries. As we can see in the growth equation (19), an increase I^W raises growth, while a reduction in I^E and an increase share of production taking place in the East ($\omega^E + \omega^M$), which implies an increase in $1 - q^W$, reduces growth. Since, even at the maximum subsidy level that we consider the West leads in more than 85% of sectors, the increase in western innovation dominates and higher western subsidies propel higher global growth.

Welfare in the West increases with western R&D subsidies. In Figure 5, we decompose the welfare effect into its different parts as in (31) and find a positive contribution of the growth channel, while the expenditure channel is less straightforward. Equation (25) suggests that besides the negative effect on consumption expenditures of the increased tax burden needed to finance the R&D subsidy, the only other impact takes place through the value of the total assets \mathcal{A}^W (equation 44). The value of western assets increases due to a rise in the share of sectors with western leadership ($\omega^W + \omega^M$), caused by higher innovation and multinational transfer. However, the tax burden which increases with the subsidy overturns this positive effect and reduces the consumption component of the welfare. Next, western firms shifting production to the East via FDI implies that the static component of aggregate prices declines, as labor cost is lower in the East.²⁷ Finally, the growth component is positive and strong, and along with

²⁶Similarly to Dinopoulos and Segerstrom (2010), lower creative destruction in the less developed country attracts more multinational production transfer. In their model though, creative destruction in the South is the exogenous rate at which North technologies are copied there, while here it is the endogenous response of eastern firms innovation to western subsidies. Hence, this effect of R&D on FDI cannot be obtained in models where the less developed region does not innovate.

²⁷Recall from (13) that $\bar{P} = [q^W p^{W(1-\sigma)} + q^M p^{M(1-\sigma)} + q^E p^{E(1-\sigma)}]^{-\frac{1}{1-\sigma}}$ is the contribution of western quality

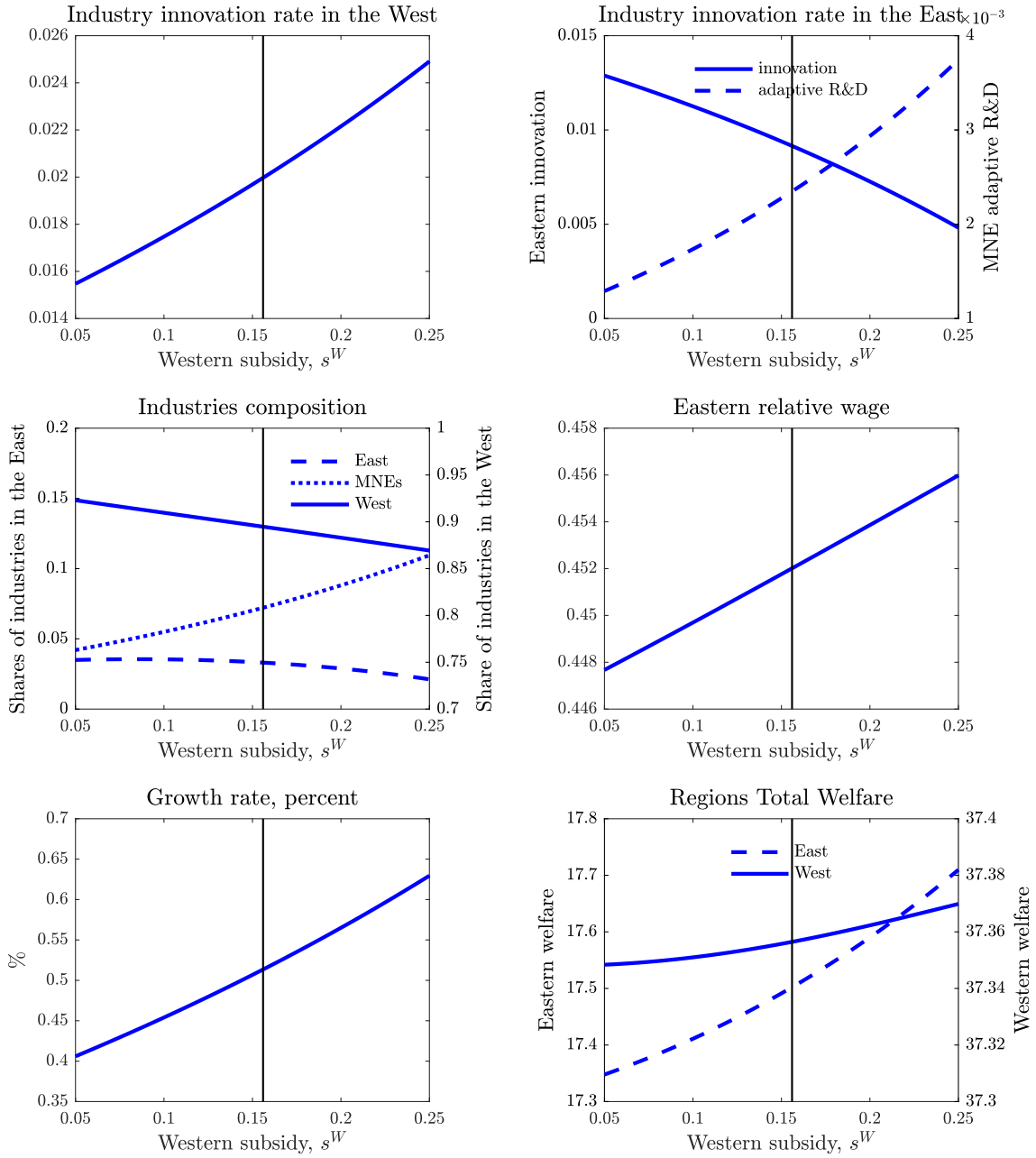


Figure 4: R&D subsidies in the West

the fall in the price component leads to a positive overall effect of West subsidies on western welfare. Eastern welfare also benefits from the increase in western subsidy. The East loses a share of its sectoral leadership and the associated assets value due to the international business stealing effect of higher western innovation. However, this loss is compensated for by the higher global growth rate and the reduction in the static price index.

These results suggest that, under our parametrisation, the business-stealing effect of sub-leaders, western affiliates and eastern quality leaders to the price index. An increase in $\omega^M - \omega^W$, and therefore in, $q^M - q^W$, reduces the contribution of West wages thereby reducing the static component of the price index.

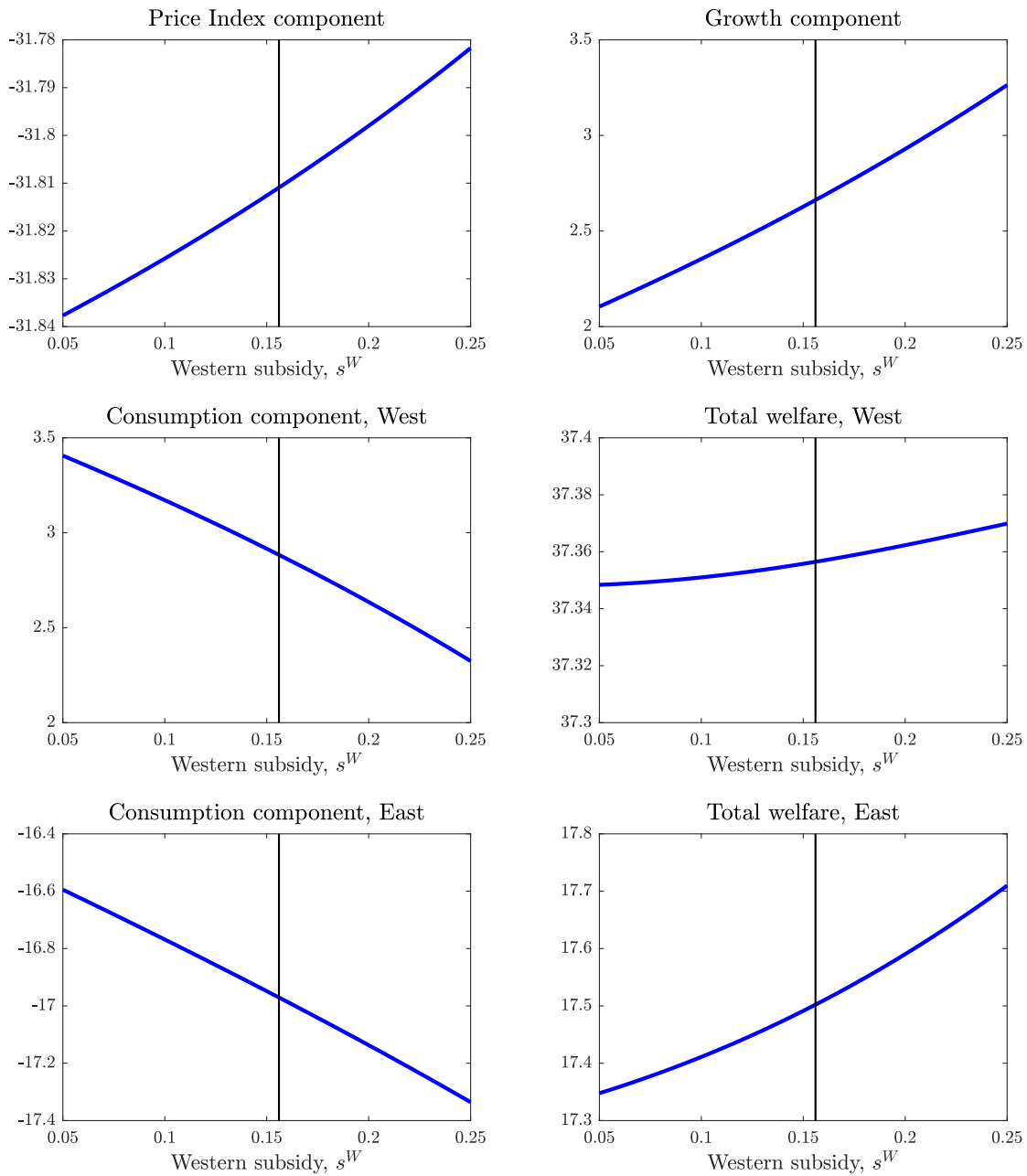


Figure 5: R&D subsidies in the West: welfare components

sidies is not strong enough to offset the welfare cost to subsidise R&D and that the growth-enhancing role of subsidies provides the key motivation in support of this policy for the western government. As a consequence, the static models, featuring in the standard strategic trade and industrial policy literature²⁸, and focusing on the profit-shifting role of subsidies miss the key role of innovation and growth in shaping the desirability of this policy tool. This fundamental role of growth will be the driving force shaping the gains from policy cooperation explored later.

²⁸See for example, Eaton and Grossman (1986), and Ossa (2015) for a modern quantitative application.

Subsidising R&D in the East. We now turn to the effects of a unilateral change of the eastern R&D subsidy, s^E . The results, shown in Figures 6 and 7, operate through similar channels as in the West. First, an increase in eastern subsidy leads to a reduction in western innovation and adaptive R&D, and an increase in eastern innovation. As before, the latter effect is a straightforward result of the reduction in innovation costs, while the reduction in western innovation comes from a stronger creative destruction generated by higher innovation in the East. Moreover, when eastern innovation increases, transferring technology abroad implies a higher risk of being leapfrogged by a local firm and, as a consequence, western firms have lower incentives to invest in adaptive innovation and move production to the East. Moreover, subsidising innovation in the East more heavily slows down global growth. An increase in eastern subsidies stimulates innovation in the East, the region that only innovates in a subset of all industries, while discouraging innovation in the West, the region where firms innovate in all sectors of the economy. The share of sectors where eastern firms innovate shrinks due to weaker multinational activity. The combination of these forces reduces global growth.²⁹

Second, as before, the changes in innovation affect the geographical distribution of market leadership. The West reduces its domination in the global market as the multinational production transfer drops. This brings more sectors back to the West (ω^W increases), but the total share of sectors with West leadership is lower due to a fall in the share of multinational sectors (ω^M). Although the adaptive innovation cost drops due to the higher subsidy, the general equilibrium effect driven by stronger creative destruction in the eastern market dominates. The set of sectors with direct eastern leadership ω^E increases, due to higher eastern innovation. These results surprisingly suggest that the less developed region cannot attract MNAs with subsidies to R&D, even though they directly reduce the cost of moving production abroad. The *threat of creative destruction*, of being copied and innovated upon, dominates the cost incentives produced by the subsidy. This is a key feature of multinational activity in a Schumpeterian economy which cannot operate in existing static models of offshoring and FDI.³⁰ Third, Lowering technology transfer and multinational activity implies a decline in the relative demand of labor in the East which is stronger than the increase generated by higher eastern leadership ω^E and, as a consequence, the eastern relative wage declines.

Finally, in Figure 7 we show the effects on welfare and its components. Western welfare decreases due to the international business-stealing effect of the subsidy. The consumption component of welfare (31) is declining for the West, driven by the subsidy-induced profit shifting. Eastern welfare, on the other hand, shows a hump-shaped response. For a lower range of sub-

²⁹ As we see in (19), growth $g = (\lambda^{\sigma-1} - 1) (I^W + (1 - q^W) I^E)$, is propelled by West innovation, taking place in all sectors, and East innovation, taking place only in the subset of sectors $(1 - q^W)$. Figure 6 shows that an increase in eastern subsidy decreases I^W and increases I^E , but also reduces the share of sectors where eastern firms innovate as it discourages production transfer to the East.

³⁰In the static models reviewed in Antràs and Yeaple (2014) a reduction in FDI cost generates an increase of multinational activity.

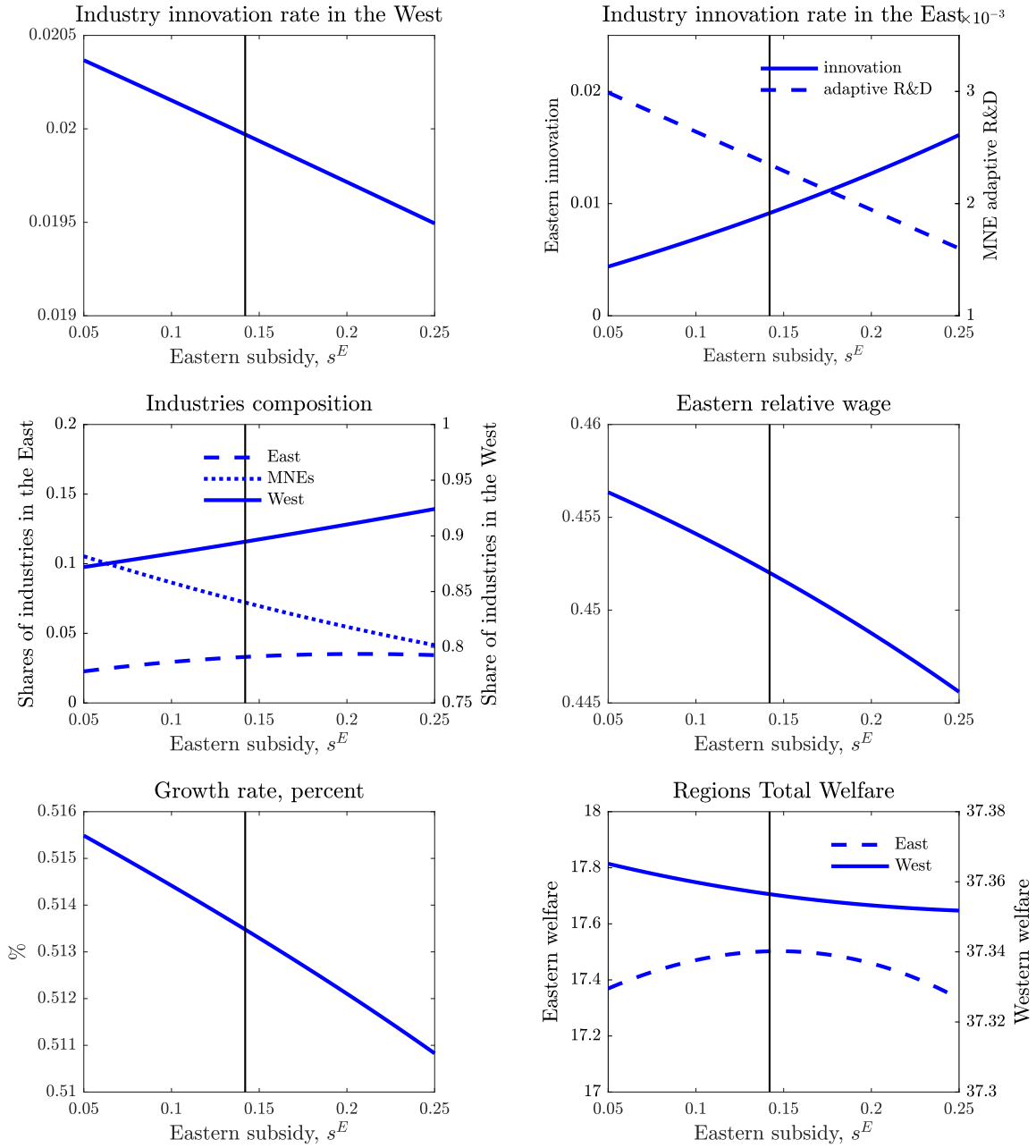


Figure 6: R&D subsidies in the East

sidy values, international business stealing favours the consumption component through profit shifting. However, increasing subsidy to high levels crowds out multinational firms, thereby reducing technological transfer and the breadth of East innovation. As a consequence, labor demand in the East drops sharply and the related reduction in eastern relative wage forces consumption in (27) to fall. The effect on the static price component \bar{P} is also negative, that is the price level increases, due to a reduction of multinational production which implies a shift of production toward the high-wage western region. Along with this negative price and growth

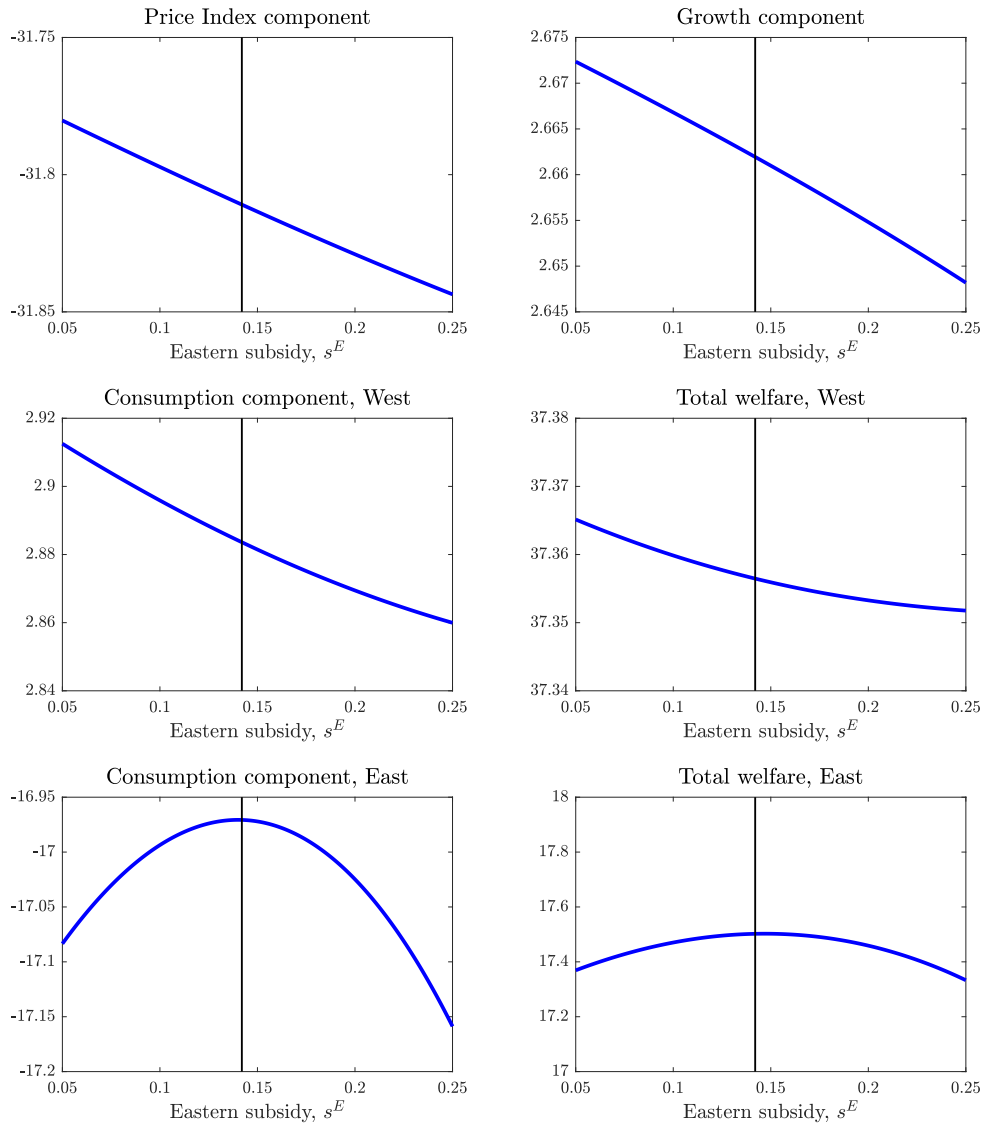


Figure 7: R&D subsidies in the East: welfare components

components, the drop in consumption eventually reduces eastern welfare.

4.3 Optimal policy scenarios

We now turn to analyse two optimal policy options. A first one in which the two regions set their subsidies non-cooperatively in order to maximise their own welfare. In the second option, a unified subsidy is chosen by an EU-level policy maker in order to maximise the joint welfare of the two regions.

4.3.1 Nash equilibrium subsidies

The optimal non-cooperative subsidies equilibrium results from a two-stage policy game between the two regions: in the first stage governments set their subsidies and in the second stage firms choose R&D and production to maximize their profits, and households choose their utility-maximizing consumption bundles and asset holdings. For each level of the other region's subsidy, policy makers set their subsidy according to their best-response functions,

$$s_n^W(s_n^E) = \arg \max \{W^W(s_n^W, s_n^E)\}, \quad (34)$$

$$s_n^E(s_n^W) = \arg \max \{W^E(s_n^W, s_n^E)\}. \quad (35)$$

This policy game yields the Nash equilibrium subsidies, s_n^{*W} and s_n^{*E} , shown in Figure 8, where we plot the two best-response functions, confirming the strategic role of subsidies. An increase in one region's R&D subsidy triggers a defensive R&D subsidy response in the other region, that is, higher levels of western subsidy lead to higher optimal subsidy in the East $s_n^{*E}(s_n^{*W})$ and vice versa.

To provide intuition for this, we refer again to the illustrative decomposition (32) and (33). The force driving the policy complementarity is the strategic motive for subsidising R&D. Abstracting from multinationals, the *IBSE* implies that when one region increases its subsidy the other region needs to do the same to protect its profits and wages. The presence of multinationals tames this effect as higher western subsidies move production/jobs to the East thereby reducing western wages, and higher eastern subsidies discourage FDI leading to lower labor demand and wages in the East. The positive sloped best-response functions in Figure 8 suggest that in our economy the potentially offsetting effect due to the presence of multinational is not strong enough to undo the strategic role of subsidies. The general equilibrium effect via wages produced by multinationals is not present in the standard partial equilibrium framework of the strategic industrial policy literature (e.g. Leahy and Neary, 1997, Haaland and Kind, 2008) and, as we will see later, it is important in shaping the effects of policy cooperation versus competition.

As we discussed above, in closed economy Schumpeterian growth models the optimal R&D subsidy can be positive or negative depending on the relative strength of the business stealing and the growth effect. In open economy, the strategic policy interaction between countries adds other forces affecting the sign of the subsidy. In our model the sign of the optimal subsidy depends on parameter specifications. Figure 8 shows that in our benchmark economy the externalities motivating public support for R&D are stronger than those requiring an R&D tax and the resulting optimal subsidies are positive. The Nash subsidies are $(s_n^W, s_n^E) = (0.458, 0.304)$, a 45% subsidy rate to western firms and a 30% subsidy rate to eastern firms, which are both substantially higher than those in the data (and in our calibration), $(s_n^W, s_n^E) = (0.156, 0.142)$.

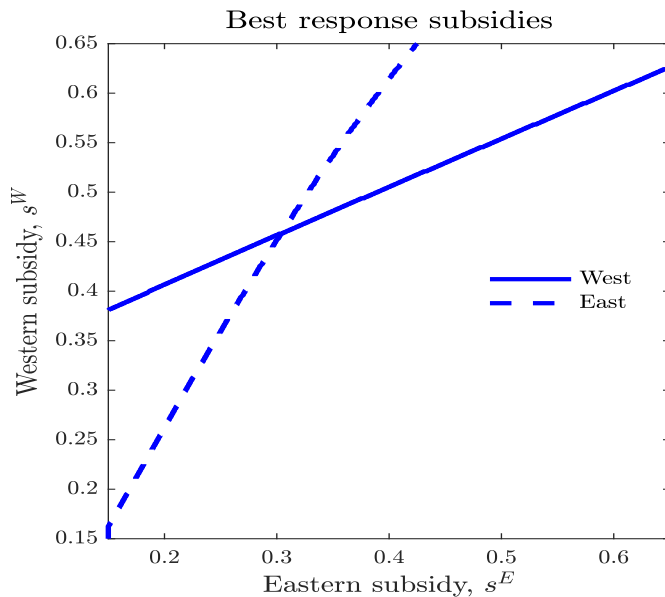


Figure 8: Nash equilibrium subsidies

4.3.2 Policy cooperation: a unified subsidy

Although the Nash subsidies are optimal from the perspective of each region separately, they are not optimal for the economic union as a whole. First, governments do not take into account the positive innovation effect of R&D subsidies on the other country's growth rate and consumer surplus. Second, the international business-stealing effect of national subsidies on foreign aggregate income is not considered by the governments when maximising their own welfare. Hence, the need for policy coordination internalising these externalities.

Since current debates on the Innovation Union and Fiscal Union focus on the idea of a unified innovation and fiscal policy, we explore one possible form of coordination, a *unified subsidy*, s_{uni} , set to maximise welfare in both regions

$$s_{uni} = \arg \max \{W^{EU}(s_{uni})\}, \quad (36)$$

where W^{EU} is the total EU welfare,

$$W^{EU} = W^W + W^E = \frac{1}{\rho - n} \left(\log c^W + \log c^E - 2 \log \bar{P} + 2 \frac{g}{(\sigma - 1)(\rho - n)} \right). \quad (37)$$

We numerically compute the optimal common subsidy and compare the welfare outcome of cooperative and non cooperative policies. In doing so, we assume that there is no ex-post compensation scheme and, consequently, cooperation may generate winners and losers.

The results are presented in Table 4. The unified policy leads to substantially higher subsidies than its non-cooperative counterpart. Growth more than doubles under the cooperative policy, while welfare increases only in the East and remains essentially unchanged in the

West. We also compute welfare gains in consumption equivalence, defined as $\chi > 0$ such that $U_n^i(\chi X_n^i) = U_{uni}^i(X_{uni}^i)$, where $i = W, E$, and X_n^i, X_{uni}^i are the allocations under Nash and unified subsidies, and U_n, U_{uni} are computed using the steady state welfare in (31), from which we also derive the decomposition of the welfare effects. The total gains are

$$\ln(\chi^i) = \ln\left(\frac{c_{uni}^i}{c_n^i}\right) - \ln\left(\frac{\bar{P}_{uni}}{\bar{P}_n}\right) + \frac{g_{uni} - g_n}{(\rho - n)(\sigma - 1)}, \quad (38)$$

for $i = W, E$, where the *IBSE* operates via consumption, $\ln(c_{uni}^i/c_n^i)$, the consumer surplus is $-\ln(\bar{P}_{uni}/\bar{P}_n)$, and the growth channel is $(g_{uni} - g_n)/((\rho - n)(\sigma - 1))$. A positive (negative) number in the decomposition represents a positive (negative) contribution of the channel to welfare.³¹ We report $\ln(\chi)$ so that the total gains are the sum of its components, but the precise total gains are measured by χ .³² Similarly, using (37), the welfare gains for the EU are

$$\ln(\chi^{EU}) = \ln\left(\frac{c_{uni}^W}{c_n^W}\right) + \ln\left(\frac{c_{uni}^E}{c_n^E}\right) - 2\ln\left(\frac{\bar{P}_{uni}}{\bar{P}_n}\right) + \frac{2(g_{uni} - g_n)}{(\rho - n)(\sigma - 1)}. \quad (39)$$

The EU-wide gains come predominantly from the gains in eastern welfare, a 5.55% increase in long-run consumption, while western gains are negligible, a 0.15% increase.

Table 4: The effect of cooperation

	s^W	s^E	W^W	W^E	W^{EU}	$growth$			
Observed (s_n^W, s_n^E)	0.1560	0.1420	37.3565	17.5022	54.8587	0.5135			
Nash (s_n^W, s_n^E)	0.4585	0.3037	37.4183	18.9469	56.3652	0.9924			
Unified (s_{uni})	0.7779	0.7779	37.4509	20.2087	57.6597	2.3135			
No subsidies ($s^W = s^E = 0$)	0	0	37.3655	17.3054	54.6709	0.3650			
Welfare gains									
Unified vs. no subsidy			0.0038	0.1275	0.1313				
Unified vs. observed			0.0041	0.1189	0.1230				
Unified vs. Nash			0.0015	0.0555	0.0570				
International business stealing			-0.3044	-0.2504	-0.5548				
Consumer surplus			0.0051	0.0051	0.0102				
Growth			0.3008	0.3008	0.6016				
Convergence	w^E/w^W	$\mathcal{A}^E/\mathcal{A}^W$	c^E/c^W	ω^E	ω^W	ω^M	I^E	I^W	I^M
Observed	0.4520	0.1757	0.4181	0.0331	0.8948	0.0722	0.0092	0.0200	0.0023
Nash	0.4576	0.0477	0.4443	0.0063	0.8485	0.1452	0.0017	0.0397	0.0071
Unified	0.4390	0.1986	0.4689	0.0350	0.9046	0.0604	0.0517	0.0894	0.0094

In order to understand the mechanisms at work here, we need to examine the effects of

³¹This decomposition only roughly accounts for the effects of subsidies on the key innovation externalities, as we cannot obtain them in a closed form.

³²The difference between the two measures is negligible.

subsidies on the objective function W^{EU} . Below we present an illustrative decomposition based on (39). Starting with the effects of the West subsidy we have,

$$\frac{\partial W^{EU}}{\partial s^W} = \underbrace{\frac{\partial \tilde{c}^W}{\partial s^W}}_{BSE} + \underbrace{\frac{\partial \tilde{c}^W}{\partial s^W}}_{IBSE} + \underbrace{\frac{\partial \tilde{c}^E}{\partial s^W}}_{IBSE} + \underbrace{2 \frac{\partial \tilde{P}}{\partial s^W}}_{CSE} + \underbrace{2 \frac{\partial \tilde{g}}{\partial s^W}}_{GRE}. \quad (40)$$

$(-)$ $(+/-)$ $(+/-)$ $(+)$ $(+)$

Comparing (40) with (32) suggests that the unified subsidy internalises the business stealing, the consumer surplus effect and the growth effect of western subsidies on the other region. Internalising the strategic motive for subsidy, the *IBSE* externality should lead to a unified subsidy lower than the Nash in both regions. The results in Table 4 show that the opposite happens, the unified subsidy is substantially larger than the Nash subsidies. The driving force of this result is that policy cooperation also internalises the consumer surplus and the growth effect of one country's subsidies on the other country's welfare. Under our benchmark parametrisation, the internalisation of the positive growth effect and of the consumer surplus effect dominate, thereby leading to a higher unified R&D subsidy than the Nash subsidies. Hence, the key reason for setting a common subsidy is not the correction of the strategic motive but the strong consumer surplus and the growth effect it produces.

This result echoes those in Leahy and Neary (1997 and 2009) and Haaland and Kind (2008), who show, in simpler frameworks, that when innovation spillovers are high, the consumer surplus effect is strong and subsidies under cooperation are higher than under Nash. In our dynamic setting knowledge spillovers impact welfare via an additional, intertemporal channel, the growth effect which proves to be quantitatively powerful and the key driver of the result, as we show below.

The illustrative decomposition of the effects of eastern subsidy based on (39) is,

$$\frac{\partial W^{EU}}{\partial s^E} = \underbrace{\frac{\partial \tilde{c}^E}{\partial s^E}}_{BSE} + \underbrace{\frac{\partial \tilde{c}^E}{\partial s^E}}_{IBSE} + \underbrace{\frac{\partial \tilde{c}^W}{\partial s^E}}_{IBSE} + \underbrace{2 \frac{\partial \tilde{P}}{\partial s^E}}_{GRE} + \underbrace{2 \frac{\partial \tilde{g}}{\partial s^E}}_{CSE}. \quad (41)$$

$(-)$ $(+)$ $(-)$ $(+)$ $(+/-)$

For the East, internalising the *IBES* also implies a smaller unified subsidy compared to Nash, but, differently from the West, eastern R&D subsidies can reduce global growth as they discourage FDI thereby reducing the scope of eastern innovation (the share of sectors where the eastern firms innovate). The results show that the unified subsidy is substantially higher than the Nash subsidy in the East as well. This suggests that, similarly to what we saw for the West, the internalisation of the consumer surplus effect and of the growth effect drive of the gains from policy cooperation.

In Table 4, we present a decomposition of the welfare gains from the unified subsidy compared to the Nash based on (39) which heuristically tracks the internalisation of the three externalities shown in (40) and (41). The international business stealing component is negative. This suggests that the higher unified subsidy relative to Nash aggravates rather than correcting the international business stealing externality. The welfare gains from cooperation attributable to the consumer surplus effect are small, about half of a percentage point. While the gains brought about by the internalisation of the growth effect are large. This suggests that the internalisation of the consumer surplus effect of innovation (and production) subsidies, typical of the static strategic industrial policy models (e.g Eaton and Grossman, 1986, and Leahy and Neary, 1997), is not sufficient to generate large welfare gains from cooperation. The key externality driving the gains from cooperation is the growth effect, or intertemporal knowledge spillover (Aghion and Howitt, 1992), which cannot be obtained in static models.

The results are similar when we compare the unified subsidy with a no policy intervention scenario (zero subsidies) and with the observed subsidies. The gains from cooperation in these scenarios for the EU as a whole are substantially larger compared to those in the Nash scenario: long-run consumption is 13% higher compared to no policy intervention, and 12% higher compared to the observed subsidies. Most of these gains are again concentrated in the East.³³

Unequal gains. Why are the gains from cooperation unequally distributed? There are essentially three reasons to cooperate: internalising the consumer surplus effect, the growth effect and the *IBSE*. Since trade is free, internalising the first two externalities benefits both countries equally. Internalising the business stealing effect, instead, has unequal welfare implications. Since the unified subsidy is higher than the Nash subsidies, policy cooperation produces more *IBSE* than the uncooperative scenario and the associated welfare losses are higher for the West (-0.3) than for the East (-0.25). This occurs because moving from the Nash to the unified scenario produces a larger subsidy increase for the latter. This implies that the East ends up stealing business from the West, thereby reducing its national income and consumption. Another, perhaps more intuitive, way to understand this result is noticing that in the Nash scenario the West leads in 99% of the sectors in the economy, either via direct leadership or via multinationals, as can be seen in Table 4. Hence, the incentives to cooperate to reign in East business stealing are then quite low. When the innovation asymmetries between the two regions are smaller, as in the observed subsidies case, the incentives to cooperate for the West are indeed larger.

Convergence. One of the key targets of the Innovation Union and of the comprehensive Europe 2020 strategy, the EU's agenda for growth and jobs for the current decade, is regional

³³We only report the total gains, the decomposition produces the same results as in the Nash case, with the growth channel dominating, and are available upon request.

cohesion, which mandates that the EU policies should promote convergence across European regions in innovation and growth performance (European Commission, 2015). We have then analysed the impact of a unified innovation subsidy on convergence of income and innovation performance. Table 4 shows relative income and innovation performance of the two regions under the observed subsidies, the Nash and the unified subsidy.

The unified subsidy promotes income convergence across regions driven by convergence in asset ownership, $\mathcal{A}^E/\mathcal{A}^W$, while it worsens the East-West gap in relative wages. Although the relative eastern wage declines, the increase in the share of firms owned by eastern households generates an increase in the income from assets stronger than the decline in relative wages, thereby triggering convergence in consumption. Uniform subsidies imply an increase in subsidy compared to Nash for both the East and the West, but more for the East. So we can understand the convergence result simply thinking about an increase in the eastern subsidy while leaving the western subsidy constant. A higher eastern subsidy increases the share of sectors led by eastern firms ω^E , thereby increasing the share of eastern assets. On the other hand the share of sectors led by western multinationals shrinks, due to increasing creative destruction, and this reduces FDI which, in turn, reduces the relative labor demand and wage in the East. The convergence in market leadership and therefore in asset ownership is due to the convergence in innovation, which can be observed in the last three columns of Table 4. Under Nash, innovation by eastern firms accounts for about 3.5% of total innovation ($I^E/(I^E + I^W + I^M)$) and about 34% under unified subsidy. The convergence in income level and consumption are quite small and, as we discussed above, most of the welfare gains for the East of adopting a unified subsidy come from the growth effect and a reduction in the quality-adjusted prices, which increasing households' purchasing power.

5 Robustness and further analysis

Next, we first conduct robustness analysis with respect to some key parameters of our economy and then explore the implications of unbundling the FDI and the R&D subsidy and of assuming that FDI is financed by Western saving, a different asset ownership structure.

5.1 Robustness

Let us first consider an increase in the efficiency of MNE's production transfer as a measure of the regions' integration. The efficiency of production transfer from the West to the East may depend on many features of the real economy. It could be, for example, shaped by the level of human capital in the East, by product standards and non-tariff barriers, such as regulations on technology adoption. In our simple economy, it is captured in a simple way by the productivity parameter of the adaptive R&D, γ^M .

In Table C.1 in the Appendix, we analyse how changes in the efficiency/cost of production transfer affect the Nash and unified subsidies regimes. The Nash subsidies declines with the efficiency of production transfer. As seen above, multinationals tame the strategic motive for subsidy: with more FDI the regions are more integrated, the rewards for a subsidy war are lower and, consequently, the optimal Nash subsidies are lower. The unified subsidy, instead, increases when FDI is more efficient. On the one hand, since the strategic motive for subsidy is weaker with more efficient FDI, the benefits from internalising the international business stealing effect are lower and so should the unified subsidy. On the other hand, if internalising the consumer surplus and growth effect becomes more important, the unified subsidy could be higher. The innovation technology (8) suggests that an increase in FDI, by increasing the breadth of innovation, raises the average quality in sectors where eastern firms innovate (Q^{E+M}) thereby increasing the aggregate knowledge spillovers these firms are exposed to and therefore their innovation efficiency. Stronger knowledge spillovers imply a stronger market failure in innovation and a stronger incentive for the EU policy maker to correct it. The larger gains from subsidy cooperation compared to competition come then from a larger role for consumer surplus and growth while the business stealing externality plays a weaker role compared to benchmark, as the strategic motive for subsidies is weaker with more FDI. As in the benchmark case, the East reaps most of the gains from cooperation, while the gains for the West are negligible.

In Table C.2, we explore robustness with respect to parameter σ , which regulates the markup. Unfortunately, we can only check the robustness to small changes, as the equilibrium is very sensitive around this parameter. Although changes are quite local, they do provide some insight. A lower markup (higher σ), reduces the importance of the international business stealing effect, as the strategic motive to shift profits across borders is driven by the size of these rents. With smaller profits, policy cooperation does not need to make a strong effort to internalise the *IBSE* which implies that the unified subsidy rises, as the growth channel becomes an ever stronger driver. However, in the absence of a large inefficiency operating through the markup and IBSE cooperation generates smaller EU gains.

5.2 Extensions

Gains from cooperation: FDI vs. innovation policy. In our benchmark model, although FDI does not directly contribute to innovation and growth, it benefits from the same subsidy as innovative R&D. In this extension, instead, the economy features an *innovation policy*, the R&D subsidy, and separate FDI subsidy, which can be seen as a more standard *trade policy*, as it affect the cost of multinational activity with no direct implications for innovation. With a few exceptions (e.g. Akcigit et al., 2018) innovation and trade policies are typically analysed separately, in different models. Our framework allows a joint analysis and permits a

decomposition of their specific contribution to the welfare gains from international policy cooperation.

In Table C.3 we report a new Nash scenario where the West and the East maximise their own welfare by setting the R&D subsidies (s_n^W, s_n^E) non-cooperatively, and the East also sets the FDI subsidy (s_n^M) to maximise its own welfare. The optimal R&D subsidy for the East is higher (0.35) than in the benchmark case (0.30). In the benchmark model a higher East R&D subsidy, on the one hand, reduces the cost of FDI but, on the other hand, increases innovation and creative destruction in the East thereby discouraging FDI. The former effect strengthens the strategic motive for subsidies while the latter weakens it. In the new scenario, instead, the former effect is zero by construction, as the R&D subsidy does not directly affect the cost of FDI, thus we would expect a lower eastern Nash R&D subsidy. However, the East finds it optimal to fully subsidise FDI ($s^M = 1$). The optimal FDI subsidy reaches the highest possible level because now it does not generate the negative effect on FDI via creative destruction, as it is unbundled from the R&D subsidy and does not directly affect eastern firms' innovation. As seen above, more FDI expands the set of sectors where eastern firms innovate (Q^{E+M}) thereby increasing the aggregate knowledge spillovers in (8) for these firms. Due to these higher spillovers the marginal effect of the East R&D subsidy on eastern welfare is larger and thus the Nash R&D subsidy rises.

Next we compute a new cooperative policy regime characterised by the unified R&D subsidy (s_{uni}) and the FDI subsidy (s_{uni}^M) set separately to maximise EU welfare. As we discussed above, when RD and FDI subsidies are separated the internalisation of the *IBSE* is more important, because the strategic motive for subsidy is stronger, but the growth effect is more powerful as well, as the knowledge spillovers generated by specific subsidies to FDI are stronger. This latter effect prevails and the optimal unified R&D subsidy is slightly higher than in the benchmark scenario of Table 4. Both the growth and welfare gains produced by policy cooperation compared to Nash are substantially larger than in the benchmark case. Now cooperation attains a 8.1% increase in long-run consumption, three percentage points larger than in the benchmark scenario. Once again most of these gains are accounted for by internalising the growth effect. To facilitate comparisons between these two scenarios we have summarised the welfare gains result in column (1) and (2) of Table 5. These larger gains are obtained because now the policy tools used can target more directly the two types of externalities: the R&D subsidy tackles the innovation externalities and the FDI subsidy tackles the externalities related to technology/production transfer. The complementarity between FDI and R&D subsidies produces the larger gains from trade: more FDI leads to stronger international knowledge spillovers which, in turn, strengthen the growth effect of innovation subsidies.

We now turn to the decomposition of the gains from cooperation in FDI and innovation policy. In Table 5, we quantify the gains from optimal innovation and those from optimal FDI

Table 5: Welfare gains of different policy regimes

Welfare gains	(1)	(2)	(3)	(4)	(5)
	Cooperative two instruments	Unified one instrument	Cooperative two instruments	Cooperative FDI only	Cooperative R&D only (3)-(4)
West	0.0022	0.0015	0.0044	-0.0008	0.0052
International business stealing	-0.3259	-0.3044	-0.4513	-0.0006	-0.4507
Consumer surplus	0.0051	0.0051	-0.0010	-0.0046	0.0036
Growth	0.3230	0.3008	0.4567	0.0044	0.4523
East	0.0788	0.0555	0.1568	0.0319	0.1249
International business stealing	-0.2493	-0.2504	-0.2989	0.0321	-0.3310
Consumer surplus	0.0051	0.0051	-0.0010	-0.0046	0.0036
Growth	0.3230	0.3008	0.4567	0.0044	0.4523
EU	0.0810	0.0570	0.1612	0.0311	0.1301
International business stealing	-0.5752	-0.5548	-0.7502	0.0315	-0.7817
Consumer surplus	0.0102	0.0102	-0.0020	-0.0046	0.0026
Growth	0.6461	0.6016	0.9133	0.0089	0.9044

Notes. Welfare gains are in consumption equivalence, computed as described in section 4.3.2. Column (1) presents the gains from optimal cooperative unified R&D subsidy and optimal cooperative FDI subsidy (s_{uni}, s_{uni}^M), relative to the Nash scenario, where s_n^W maximises W welfare and s_n^E and s_n^M maximise E welfare. Column (2) reports the benchmark results in Table 4, i.e. gains of cooperation when R&D and FDI policy instruments are bundled. The following columns present the gains relative to the no subsidies regime ($s^W = s^E = s^M = 0$) of the following regimes: (3) Optimal unified R&D subsidy and optimal cooperative (set to maximise EU welfare) FDI subsidy (s_{uni}, s_{uni}^M), (4) optimal cooperative FDI subsidy (s_{uni}^M) with no R&D policy ($s^W = s^E = 0$), and (5) as the difference between (3) and (4) isolating the gains from optimal R&D policy only.

policy with respect to a scenario where no policies are in place.³⁴ In column (3) we report the gains from policy cooperation using the two instruments, R&D subsidy and FDI subsidies separately, while in column (4) we report at the gains from optimal cooperative FDI policy alone. The overall gains of cooperation versus no policy are larger, 16.1% in the case of two instruments than in the benchmark case reported in Table 4, which amount to 13.1%. The gains are again uneven, with the East benefiting substantially while the West actually loses, though not substantially. The key driver is again the dynamic gains produced by policy cooperation via the growth channel. The losses come from the static consumer surplus channel. There are two effects of increasing FDI on the static component of the price index \bar{P} . Moving production to the low-wage region reduces the price index, but higher FDI also increase the wage in the low-wage region, thereby increasing the price index. The latter force prevails and leads to small losses from heavily subsidising FDI.

Column (4) shows that FDI policy alone generates the small losses via the consumer surplus

³⁴Bartelme et al. (2018) present a similar decomposition but focus on the comparison between industrial (production subsidies) and trade policy rather than innovation and FDI, and do not consider strategic policy interactions between countries. In fact, the optimal policy is set independently and separately by each country, which is a viable option as they assume that each country is a small-open economy. In our framework, regions are large and retaliation matters, so we consider the strategic policy interaction, and analyse both the Nash and the cooperative scenario. We report only the latter here for brevity.

channel just discussed. Moreover, although growth still contributes positively to the gains from setting the FDI subsidy cooperatively, it is not the main driver anymore. This is straightforward as FDI does not contribute directly to innovation and growth. The gains now operate mostly via increasing nominal income in the East, the *IBSE*. An increase in FDI increases the wage in the East but, at the same time, reduces the value of the assets owned by eastern households, as the difference between v^M and v^W in (45) goes to zero when the FDI subsidy is one, which is the case under cooperation, as shown in Table C.3 . The wage effect dominates and eastern income increases.

Column (5) reports the gains attributable to cooperative R&D policy only. The gains from innovation policy alone are again concentrated in the East (12.49%) and are remarkably similar to those obtained in the benchmark case with bundled subsidy in Table 4 (12.45%). The gains for the EU in the two cases are identical. This suggests that tying the FDI policy to the innovation policy does not generate any additional gains. While comparing (4) and (5) we can see that a separate FDI subsidy produces extra gains equivalent to about 3% higher long-run consumption. As in the benchmark case, the strong innovation policy under cooperation is always harmful through the *IBSE* channel and always beneficial via the *growth* channel, which is now stronger. The source of the larger gains is the complementarity between FDI and innovation subsidies operating via the effect of the latter on the width and strength of knowledge spillovers.

Alternative asset specification. Next, we explore an alternative assets specification where the adaptive R&D, or FDI cost, which allows the West to transfer production to the East is financed by western savings. In this case, western consumers appropriate the extra profit obtained through cheaper MNE's production. The key departure is that the asset values (44) and (45) now become³⁵

$$\mathcal{A}^W = \int_{\omega^W} \frac{v^W(\omega)}{L^W(t)} d\omega + \int_{\omega^M} \frac{v^M(\omega)}{L^W(t)} d\omega, \quad \mathcal{A}^E = \int_{\omega^E} \frac{v^E}{L^E(t)}(\omega) d\omega.$$

The West can appropriate the full value of transferring production and this increases the strategic motive to subsidise R&D in the West and move production abroad. In Table (C.4), we report the Nash, the unified subsidy and their welfare and growth implications under this alternative asset allocation. Higher rents from production transfer incentivise FDI and promote stronger western innovation which in turn triggers higher business stealing effects and a stronger policy response in the form of a significantly higher Nash subsidies. For the East, now FDI is less effective in taming the strategic motive for subsidy, as it does not get the extra profit of western multinationals. Hence, a higher strategic motive leads to a higher Nash subsidy for the East

³⁵The derivation of the new asset values and the effect of unilateral subsidy change are shown in the Appendix C.1.

as well. In such a scenario with high Nash subsidies, cooperation is less driven by the growth channel relative to the benchmark scenario, while the *IBSE* internalisation is more important and generates larger gains (or smaller losses) compared to the benchmark. Overall, welfare gains are still substantial but smaller than in our benchmark scenario.

In the Appendix, we also present the results of the unbundled FDI and R&D policies exercise in Table (C.5) and (C.6) and show that the key findings are essentially confirmed under this alternative asset allocation.

6 Conclusion

In this paper we have documented large asymmetries in innovation performance and policy between old and new members of the European Union. We have also presented robust firm-level evidence of western FDI spillovers on eastern firms' innovation. Motivated by these facts and by EU plans for further integration of innovation policy we have built a two-region endogenous growth model to analyse the cost and benefits of innovation policy cooperation in an economic union. The two regions feature firms competing in innovation for market leadership and are integrated via free trade and costly technology transfer via FDI.

We have shown that cooperation in the form of a unified subsidy at the Union level generates large welfare gains compared to the non-cooperative Nash subsidy scenario. Most of these gains come from the internalisation of the effect of subsidies on the growth rate of the economy. These dynamic gains are substantially larger than the static gains from internalising the strategic motive for subsidies according to which countries compete to steal wages and profits from each other. The presence of technology transfer and multinational production tames the strategic motive for subsidies and increases the gains from cooperation. We have also shown that unbundling the innovation policy, the RD subsidy, from the FDI subsidy, a more standard trade policy, leads to larger gains from policy cooperation. This policy complementarity arises from international knowledge spillovers brought about by Western FDI. By allowing eastern firms to start innovating in a larger number of industries and by increasing their innovation efficiency, FDI increase the marginal effect of R&D subsidies on innovation and growth.

For simplicity, we abstract from a third non-EU country (rest of the World) and focus on two regions as a first step towards analysing the theoretical mechanisms driving the incentives to cooperate in innovation policy within an economic union. Introducing a third country would be an important generalisation, but its inclusion would complicate the analysis substantially for the current purpose. We leave this challenging generalisation to future research.

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Appendix

A Robustness on firm-level estimations

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	count	dummy	count
	(1)	(2)	(3)	(4)
	Manufacturing		Service	
Foreign presence	0.034** (0.013)	0.021*** (0.004)	0.023 (0.019)	0.007** (0.003)
Observations	4,612	4,612	6,853	6,853
R-squared	0.234	0.234	0.219	0.219
	Private firms		State-owned firms	
Foreign presence	0.035*** (0.013)	0.012*** (0.003)	-0.019 (0.176)	-0.019 (0.176)
Observations	11,328	11,328	96	96
R-squared	0.207	0.207	0.686	0.686
	Sales above median		Sales below median	
Foreign presence	0.044** (0.018)	0.012** (0.005)	0.030** (0.014)	0.013*** (0.003)
Observations	5,676	5,676	5,602	5,602
R-squared	0.219	0.218	0.221	0.222
	Exporters		Non-exporters	
Foreign presence	0.038** (0.018)	0.014* (0.007)	0.032* (0.017)	0.009** (0.003)
Observations	2,516	2,516	8,941	8,941
R-squared	0.236	0.236	0.209	0.209
	Importers		Non-importers	
Foreign presence	0.035 (0.023)	0.031** (0.013)	0.027* (0.015)	0.008** (0.003)
Observations	2,560	2,560	8,903	8,903
R-squared	0.225	0.226	0.203	0.203

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's derivations

Labor market clearing. We derive the labor market clearing condition in the West as

$$\begin{aligned}\ell^W &= \int_{\omega^W} a^W q(\omega, t) p^{W(-\sigma)} \frac{c}{P(t)^{1-\sigma}} d\omega + \int_0^1 \frac{I^W}{A^W} \frac{X(t)}{L(t)} d\omega \\ &= \left(\frac{\sigma}{\sigma-1}\right)^{-\sigma} a^{W(1-\sigma)} \frac{c}{P(t)^{1-\sigma}} Q^W(t) + \frac{I^W 2\kappa}{\gamma^W}.\end{aligned}\quad (42)$$

where $Q(t) = \int_0^1 q(\omega, t) d\omega$ and $Q^W(t) = \int_{\omega^W} q(\omega, t) d\omega$. Also, $Q^E(t) = \int_{\omega^E} q(\omega, t) d\omega$, $Q^M(t) = \int_{\omega^M} q(\omega, t) d\omega$ and $Q(t) = Q^W(t) + Q^E(t) + Q^M(t)$. In the East we obtain,

$$\begin{aligned}1 - \ell^W &= \int_{\omega^M} a^M q(\omega, t) p^{M(-\sigma)} \frac{c}{P(t)^{1-\sigma}} d\omega + \int_{\omega^E} a^E q(\omega, t) p^{E(-\sigma)} \frac{c}{P(t)^{1-\sigma}} d\omega \\ &+ \int_{\omega^W} \frac{I^M}{A^M} \frac{X(t)}{L(t)} d\omega + \int_{\omega^E + \omega^M} \frac{I^E}{A^E} \frac{X(t)}{L(t)} d\omega \\ &= \left(\frac{\sigma}{\sigma-1}\right)^{-\sigma} a^{M(1-\sigma)} w^{E(-\sigma)} \frac{c}{P(t)^{1-\sigma}} Q^M(t) + \left(\frac{\sigma}{\sigma-1}\right)^{-\sigma} a^{E(1-\sigma)} w^{E(-\sigma)} \frac{c}{P(t)^{1-\sigma}} Q^E(t) \\ &+ \frac{I^M 2\kappa}{\gamma^M} \frac{Q^W(t)}{Q(t)} + \frac{I^E 2\kappa}{\gamma^E}.\end{aligned}\quad (43)$$

Assets. Using the free entry conditions, we can derive the per capita assets of the two countries as

$$\begin{aligned}\mathcal{A}^W &= \int_{\omega^W + \omega^M} \frac{v^W(\omega)}{L^W(t)} d\omega \\ &= \int_{\omega^W} (1 - s^W) \frac{2\kappa}{\gamma^W \ell^W} \frac{q(\omega, t)}{Q(t)} d\omega + \int_{\omega^M} (1 - s^W) \frac{2\kappa}{\gamma^W \ell^W} \frac{q(\omega, t)}{Q(t)} d\omega \\ &= (1 - s^W) \frac{2\kappa}{\gamma^W \ell^W} (q^W(t) + q^M(t)),\end{aligned}\quad (44)$$

in the West, and similarly for the East

$$\begin{aligned}\mathcal{A}^E &= \int_{\omega^E} \frac{v^E(\omega)}{L^E(t)} d\omega + \int_{\omega^M} \frac{v^M(\omega) - v^W(\omega)}{L^E(t)} d\omega \\ &= \int_{\omega^E} (1 - s^E) w^E \frac{2\kappa}{\gamma^E (1 - \ell^W)} \frac{q(\omega, t)}{Q^{E+M}(t)} d\omega + \int_{\omega^M} (1 - s^E) w^E \frac{2\kappa}{\gamma^M (1 - \ell^W)} \frac{q(\omega, t)}{Q(t)} d\omega \\ &= (1 - s^E) w^E \frac{2\kappa}{\gamma^E (1 - \ell^W)} \frac{q^E(t)}{q^E(t) + q^M(t)} + (1 - s^E) w^E \frac{2\kappa}{\gamma^M (1 - \ell^W)} q^M(t).\end{aligned}\quad (45)$$

Expenditures. Substituting the two conditions above in the expressions for per-capita consumer expenditure (25) and (27) we obtain the steady-state per capita consumption as

$$\begin{aligned}c^W &= 1 + (\rho - n)(1 - s^W) \frac{2\kappa}{\gamma^W \ell^W} (q^W(t) + q^M(t)) \\ &- \int_{\omega} s^W I^W \frac{2\kappa}{\gamma^W \ell^W} \frac{q(\omega, t)}{Q(t)} d\omega \\ &= 1 + (\rho - n)(1 - s^W) \frac{2\kappa}{\gamma^W \ell^W} (q^W(t) + q^M(t)) - s^W I^W \frac{2\kappa}{\gamma^W \ell^W},\end{aligned}\quad (46)$$

for the West, and similarly for the East

$$\begin{aligned}
c^E &= w^E + (\rho - n) \left((1 - s^E) w^E \frac{2\kappa}{\gamma^E (1 - \ell^W)} \frac{q^E(t)}{q^E(t) + q^M(t)} + (1 - s^E) w^E \frac{2\kappa}{\gamma^M (1 - \ell^W)} q^M(t) \right) \\
&- \int_{\omega^M + \omega^E} s^E I^E w^E \frac{2\kappa}{\gamma^E (1 - \ell^W)} \frac{q(\omega, t)}{Q^{M+E}(t)} d\omega - \int_{\omega^W} s^E I^M w^E \frac{2\kappa}{\gamma^M (1 - \ell^W)} \frac{q(\omega, t)}{Q(t)} d\omega \\
&= w^E \left[1 + (\rho - n)(1 - s^E) \frac{2\kappa}{1 - \ell^W} \left(\frac{1}{\gamma^E} \frac{q^E(t)}{q^E(t) + q^M(t)} + \frac{q^M(t)}{\gamma^M} \right) - s^E \frac{2\kappa}{1 - \ell^W} \left(\frac{I^E}{\gamma^E} + \frac{I^M q^W(t)}{\gamma^M} \right) \right].
\end{aligned} \tag{47}$$

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

$$\begin{aligned}
Q(t) &= \int_{\omega^W} q(\omega, t) d\omega + \int_{\omega^E} q(\omega, t) d\omega + \int_{\omega^M} q(\omega, t) d\omega \\
&= Q^W(t) + Q^E(t) + Q^M(t),
\end{aligned} \tag{48}$$

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 East 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

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

which gives

$$\dot{Q}^W(t) = (\lambda^{\sigma-1} - 1) I^W Q^W(t) + \lambda^{\sigma-1} I^W (Q^E(t) + Q^M(t)) - I^M Q^W(t). \tag{49}$$

Similarly, for the aggregate quality in the East and multinationals' production,

$$\begin{aligned}
\dot{Q}^E(t) &= \int_{\omega^E} [\lambda^{(\sigma-1)(j(\omega, t)+1)} - \lambda^{(\sigma-1)j(\omega, t)}] I^E d\omega + \int_{\omega^M} \lambda^{(\sigma-1)(j(\omega, t)+1)} I^E d\omega \\
&- \int_{\omega^E} \lambda^{(\sigma-1)j(\omega, t)} I^W d\omega \\
&= (\lambda^{\sigma-1} - 1) I^E Q^E(t) + \lambda^{\sigma-1} I^E Q^M(t) - I^W Q^E(t),
\end{aligned} \tag{50}$$

$$\begin{aligned}
\dot{Q}^M(t) &= \int_{\omega^W} \lambda^{(\sigma-1)j(\omega, t)} I^M d\omega - \int_{\omega^M} \lambda^{(\sigma-1)j(\omega, t)} I^W d\omega \\
&- \int_{\omega^M} \lambda^{(\sigma-1)j(\omega, t)} I^E d\omega \\
&= I^M Q^W(t) - (I^W + I^E) Q^M(t).
\end{aligned} \tag{51}$$

Invariance of industry 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. The average product quality of all the production in the East is given by

$$Q^{EM}(t) = Q^E(t) + Q^M(t),$$

and therefore Q^{EM} evolves according to

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

Equating the growth of quality aggregates in the West and in the East, $\frac{\dot{Q}^W(t)}{Q^W(t)} = \frac{\dot{Q}^{EM}(t)}{Q^{EM}(t)}$, equation (17) is obtained

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

Similarly, the growth rate of quality aggregates of the Eastern firms and the multinationals 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 (18) as

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

Finally, adding (49), (50) and (51) and dividing by $Q(t)$ we obtain equation (19).

Solving the model. Combining the arbitrage conditions for the West and the East (14 and 15) gives

$$w^E(t)^\sigma = \left(\frac{a^E}{a^W} \right)^{1-\sigma} \frac{\gamma^E}{\gamma^W} \frac{1-s^W}{1-s^E} \frac{\rho + I^W - n + g}{\rho + I^W + I^E - n + g} (q^E(t) + q^M(t)) \quad (52)$$

Combining the arbitrage conditions for the East and the multinationals (15 and 16) we obtain

$$w^E(t)^{\sigma-1} = \left[\left(\frac{a^M}{a^E} \right)^{1-\sigma} - \frac{\gamma^E}{\gamma^M} (q^E(t) + q^M(t)) \right] \left(\frac{a^E}{a^W} \right)^{1-\sigma} \frac{\rho + I^W - n + g}{\rho + I^W + I^E - n + g}. \quad (53)$$

Note that equations 52 and 53 solve for the relative wage or for the relative quality in the West, i.e.

$$w^E(t) = \left[\left(\frac{a^M}{a^E} \right)^{1-\sigma} - \frac{\gamma^E}{\gamma^M} (q^E(t) + q^M(t)) \right]^{-1} \frac{\gamma^E}{\gamma^W} \frac{1-s^W}{1-s^E} (q^E(t) + q^M(t)), \quad (54)$$

or

$$q^W(t) = 1 - \left[(w^E)^{-1} + \frac{\gamma^W}{\gamma^M} \frac{1-s^E}{1-s^W} \right]^{-1} \left(\frac{a^M}{a^E} \right)^{1-\sigma} \frac{\gamma^W}{\gamma^E} \frac{1-s^E}{1-s^W}. \quad (55)$$

Combining the arbitrage and the labor market clearing conditions for the West (14 and 42) equation below follows

$$\ell^W = (\sigma - 1)(1 - s^W) \frac{2\kappa}{\gamma^W} q^W(t)(\rho + I^W - n + g) + I^W \frac{2\kappa}{\gamma^W} \quad (56)$$

Combining the arbitrage and the labor market conditions for the East (15 and 43) equation below is derived

$$\begin{aligned} 1 - \ell^W &= \left[\left(\frac{a^M}{a^E} \right)^{1-\sigma} \frac{q^M(t)}{1 - q^W(t)} + \frac{q^E(t)}{1 - q^W(t)} \right] (\rho + I^W + I^E - n + g)(\sigma - 1) \frac{(1 - s^E)2\kappa}{\gamma^E} \\ &+ I^M \frac{2\kappa}{\gamma^M} q^W(t) + I^E \frac{2\kappa}{\gamma^E}. \end{aligned} \quad (57)$$

Finally, using $q^W + q^E + q^M = 1$, conditions on quality aggregates evolution and the growth rate of average quality $Q(t)$ (17, 18 and 19) become

$$\lambda^{\sigma-1} I^W q^W(t)^{-1} = I^M (1 - q^W(t))^{-1} + (\lambda^{\sigma-1} - 1) I^E, \quad (58)$$

$$\frac{q^W(t)}{1 - q^W(t)} = \lambda^{\sigma-1} \frac{I^E}{I^M} \frac{q^M(t)}{q^E(t)}, \quad (59)$$

$$(\lambda^{\sigma-1} - 1) [I^W + (1 - q^W(t)) I^E] = g. \quad (60)$$

Equations 52, 55, 56, 57, 58, 59 and 60 constitute a system of 7 equations endogenous in $I^W, I^E, I^M, \frac{w^E}{w^W}, g, \frac{Q^W(t)}{Q(t)}$ and $\frac{Q^E(t)}{Q(t)}$ which solves for these variables.

B.1 Calibration strategy

The first step in our calibration strategy is to calculate the shares of industries with the leadership of each of the two regions from the data. Given the lack of firm ownership information, particularly for the countries in the East group, we use the information on GDP and the Foreign Direct Investment (FDI) within-EU27 and external.³⁶ First, we exclude the external (non-EU) FDI stock in the EU27 area from the regions' and the area's total GDP. The share of EU15 GDP (excluding FDI from the EU12 to the EU15) in the total EU27 GDP represents the share of sectors with the leadership of the West, ω^W . The share of EU12 GDP (excluding EU15 FDI in the EU12) in the total EU27 GDP represents the share of sectors with the leadership of the East, ω^E . Finally, we use the EU15 FDI stock in the EU12 as a share of the EU27 GDP to represent the share of sectors under the control of Western subsidiary firms in the East, ω^M .

Using equations (22)-(24) that determine ω^W , ω^E and ω^M as the functions of innovation rates across industry groups, we calculate the innovation rates I^W , I^E and I^M . Next we use the innovation rates and the target for the growth rate in the set of equations (58)-(60) which describe the evolution of the quality aggregates and the growth rate of average quality. This solves for the relative qualities, q^W , q^E , and q^M , and calibrates the quality jump, λ . We proceed with the calibration of the R&D and production productivity parameters, $(\gamma^W, \gamma^E, \gamma^M)$ and (a^E, a^M) respectively. Western innovation rate and the relative quality pin down the R&D productivity parameter γ^W through (56) which combines the labor market clearing and arbitrage conditions in the West. To calibrate the innovation and adaptation productivity parameters in the East, γ^E and γ^M , we use two sets of equilibrium equations: the expressions for per capita consumption and assets in the two regions, (25, 27) and (44, 45) respectively, on the one hand, and the labor market clearing condition in the East on the other hand.

Namely, writing GDP per capita as the sum of consumption and taxes per capita and that in relative West-East terms, one obtains

$$\frac{GDP_{pc}^W}{GDP_{pc}^E} = \frac{c^W + \tau^W}{c^E + \tau^E} = \frac{1 + (\rho - n)\mathcal{A}^W}{w^E + (\rho - n)\mathcal{A}^E}. \quad (61)$$

Dividing by the Eastern relative wage and substituting for the asset terms we derive

$$\frac{GDP_{pc}^W}{GDP_{pc}^E w^E} = \frac{1 + (\rho - n)(1 - s^W) \frac{2\kappa L}{\gamma^W L^W} (q^W + q^M)}{1 + (\rho - n)(1 - s^E) \frac{2\kappa L}{L^E} \left(\frac{q^E}{\gamma^E (q^E + q^M)} + \frac{q^M}{\gamma^M} \right)}, \quad (62)$$

where the left-hand side can be calculated using our targets on the R&D cost shares, labor shares and benchmark subsidies as $\frac{GDP_{pc}^W}{GDP_{pc}^E w^E} = \frac{1-s^W}{1-s^E} \frac{L_{Rsh}^W}{L_{Rsh}^E} \frac{C_{Rsh}^E}{C_{Rsh}^W}$. Condition (62) then presents the first equation in γ^E and γ^M . The second equation in γ^E and γ^M is the expression for the (targeted) share of R&D labor in the East, i.e. the second term in the labor market clearing condition (43). These two conditions pin down the R&D productivity parameters for innovation and adaptation in the East, γ^E and γ^M .

We then turn to the rest of the equilibrium equations to calibrate the production productivity parameters a^E and a^M . We use equation (57) that links the labor market clearing and arbitrage in the East to solve for the relative production labor productivity in eastern and multinational firms,

³⁶EU27 stands for the European Union of the year 2007, i.e before the latest addition of Croatia as its member in 2013. It 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 EU12 (new members, the East) which includes Cyprus, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Slovakia, Slovenia, Bulgaria and Romania.

$\frac{a^M}{a^E}$. This ratio is then used in (54) which combines the three arbitrage conditions to solve for the eastern relative wage. Finally, we use the relative wage in any of the arbitrage conditions (52 or 53) to determine the production labor productivity in the eastern firms (a^E), and consequently the one in the multinational firms as well (a^M). Although we are not targeting the relative wage of 0.6 that we observe in the data, the wage resulting from our benchmark simulation is 0.45 and it satisfies the “product cycle “ conditions expressed in section 3.2.

C Robustness and extensions

Table C.1: Cooperation under lower cost of EU integration

	s^W	s^E	W^W	W^E	W^{EU}	<i>growth</i>			
5% decrease ($\gamma^M = 1.2318$)									
Nash (s_n^W, s_n^E)	0.4607	0.3070	37.4184	18.8949	56.3033	0.9957			
Unified (s_{uni})	0.7769	0.7769	37.4487	20.1095	57.5582	2.3035			
Welfare gains									
Unified vs. Nash			0.0013	0.0538	0.0551				
International business stealing			-0.3013	-0.2489	-0.5502				
Consumer surplus			0.0049	0.0049	0.0098				
Growth			0.2978	0.2978	0.5956				
Convergence	w^E/w^W	$\mathcal{A}^E/\mathcal{A}^W$	c^E/c^W	ω^E	ω^W	ω^M	I^E	I^W	I^M
Nash	0.4562	0.0487	0.4431	0.0063	0.8505	0.1432	0.0018	0.0399	0.0070
Unified	0.4381	0.1975	0.4669	0.0345	0.9054	0.0601	0.0512	0.0890	0.0093
25% increase ($\gamma^M = 1.6208$)									
Nash (s_n^W, s_n^E)	0.4529	0.2948	37.4191	19.2190	56.6381	0.9869			
Unified (s_{uni})	0.7829	0.7829	37.4552	20.6073	58.0625	2.3619			
Welfare gains									
Unified vs. Nash			0.0016	0.0610	0.0626				
International business stealing			-0.3172	-0.2578	-0.5750				
Consumer surplus			0.0057	0.0057	0.0114				
Growth			0.3131	0.3131	0.6262				
Convergence	w^E/w^W	$\mathcal{A}^E/\mathcal{A}^W$	c^E/c^W	ω^E	ω^W	ω^M	I^E	I^W	I^M
Nash	0.4631	0.0442	0.4496	0.0065	0.8403	0.1532	0.0017	0.0395	0.0075
Unified	0.4424	0.2033	0.4771	0.0368	0.9015	0.0617	0.0543	0.0910	0.0099
50% increase ($\gamma^M = 1.9449$)									
Nash (s_n^W, s_n^E)	0.4482	0.2878	37.4194	19.4032	56.8226	0.9818			
Unified (s_{uni})	0.7849	0.7849	37.4659	21.8818	58.3476	2.3850			
Welfare gains									
Unified vs. Nash			0.0020	0.0649	0.0669				
International business stealing			-0.3237	-0.2608	-0.5845				
Consumer surplus			0.0062	0.0062	0.0124				
Growth			0.3195	0.3195	0.6390				
Convergence	w^E/w^W	$\mathcal{A}^E/\mathcal{A}^W$	c^E/c^W	ω^E	ω^W	ω^M	I^E	I^W	I^M
Nash	0.4670	0.0417	0.4533	0.0067	0.8344	0.1590	0.0017	0.0393	0.0078
Unified	0.4449	0.2064	0.4827	0.0381	0.8992	0.0627	0.0557	0.0917	0.0103

Table C.2: Cooperation with varying elasticity of substitution (σ)

	s^W	s^E	W^W	W^E	W^{EU}	<i>growth</i>			
2% decrease ($\sigma = 4.41$)									
Nash (s_n^W, s_n^E)	0.4171	0.2725	38.3485	19.5644	57.9129	0.9367			
Unified (s_{uni})	0.7660	0.7660	38.3348	20.9796	59.3144	2.2687			
Welfare gains									
Unified vs. Nash			-0.0006	0.0622	0.0616				
International business stealing			-0.3088	-0.2460	-0.5548				
Consumer surplus			0.0049	0.0049	0.0098				
Growth			0.3033	0.3033	0.6066				
Convergence	w^E/w^W	$\mathcal{A}^E/\mathcal{A}^W$	c^E/c^W	ω^E	ω^W	ω^M	I^E	I^W	I^M
Nash	0.4563	0.0619	0.4382	0.0103	0.8550	0.1348	0.0029	0.0377	0.0101
Unified	0.4378	0.1958	0.4666	0.0346	0.9048	0.0606	0.0506	0.0884	0.0093
2% increase ($\sigma = 4.59$)									
Nash (s_n^W, s_n^E)	0.4954	0.3327	36.4924	18.3223	54.8147	1.0446			
Unified (s_{uni})	0.7898	0.7898	36.5738	19.4439	56.0177	2.3625			
Welfare gains									
Unified vs. Nash			0.0036	0.0493	0.0529				
International business stealing			-0.3017	-0.2560	-0.5577				
Consumer surplus			0.0052	0.0052	0.0104				
Growth			0.3001	0.3001	0.6002				
Convergence	w^E/w^W	$\mathcal{A}^E/\mathcal{A}^W$	c^E/c^W	ω^E	ω^W	ω^M	I^E	I^W	I^M
Nash	0.4588	0.0341	0.4502	0.0023	0.8421	0.1555	0.0006	0.0416	0.0078
Unified	0.4402	0.2016	0.4713	0.0353	0.9044	0.0603	0.0530	0.0904	0.0096
10% increase ($\sigma = 4.95$)									
Nash (s_n^W, s_n^E)	0.6299	0.4833	33.3119	16.4304	49.7423	1.3113			
Unified (s_{uni})	0.8314	0.8314	33.5424	16.7988	50.3412	2.5765			
Welfare gains									
Unified vs. Nash			0.0101	0.0162	0.0263				
International business stealing			-0.2827	-0.2767	-0.5594				
Consumer surplus			0.0048	0.0048	0.0096				
Growth			0.2881	0.2881	0.5762				
Convergence	w^E/w^W	$\mathcal{A}^E/\mathcal{A}^W$	c^E/c^W	ω^E	ω^W	ω^M	I^E	I^W	I^M
Nash	0.4607	0.0291	0.4764	0.0003	0.8290	0.1707	0.0001	0.0504	0.0049
Unified	0.4444	0.2135	0.4793	0.0366	0.9039	0.0595	0.0585	0.0950	0.0101

Table C.3: Unbundling FDI (s^M) and R&D (s^W, s^E) policy instruments

	s^W	s^E	s^M	W^W	W^E	W^{EU}	<i>growth</i>		
Nash subsidies (s_n^W, s_n^E, s_n^M)*	0.4252	0.3581	1	37.4158	19.0801	56.4959	0.9520		
Cooperative policy (s_{uni}, s_{coop}^M)**	0.7793	0.7793	1	37.4655	20.8752	58.3407	2.3707		
Welfare gains									
Cooperative policy (s_{uni}, s_{coop}^M) vs. Nash (s_n^W, s_n^E, s_n^M)				0.0022	0.0788	0.0810			
International business stealing				-0.3259	-0.2493	-0.5752			
Consumer surplus				0.0051	0.0051	0.0102			
Growth				0.3230	0.3230	0.6461			
Convergence	w^E/w^W	$\mathcal{A}^E/\mathcal{A}^W$	c^E/c^W	ω^E	ω^W	ω^M	I^E	I^W	I^M
Nash	0.4834	0.0995	0.4470	0.0287	0.8350	0.1363	0.0079	0.0374	0.0074
Unified R&D subsidies	0.4654	0.1886	0.4826	0.0432	0.8751	0.0817	0.0481	0.0910	0.0130
Welfare gains									
Cooperative policy (s_{uni}, s_{coop}^M) vs. Unified all (s_{uni})***				0.0006	0.0293	0.0299			
International business stealing				-0.0082	0.0205	0.0123			
Consumer surplus				-0.0042	-0.0042	-0.0085			
Growth				0.0130	0.0130	0.0261			
Convergence	w^E/w^W	$\mathcal{A}^E/\mathcal{A}^W$	c^E/c^W	ω^E	ω^W	ω^M	I^E	I^W	I^M
Unified all (s_{uni})	0.4390	0.1986	0.4689	0.0350	0.9046	0.0604	0.0517	0.0894	0.0094
Cooperative policy (s_{uni}, s_{coop}^M)	0.4654	0.1886	0.4826	0.0432	0.8751	0.0817	0.0481	0.0910	0.0130

Notes. Welfare gains are in consumption equivalence, computed as described in section 4.3.2.

* In the Nash regime (s_n^W, s_n^E, s_n^M) West and East are maximising own country's welfare by setting the R&D subsidies (s_n^W, s_n^E) non-cooperatively, and East also sets the non-cooperative FDI subsidy (s_n^M). **The cooperative policy (s_{uni}, s_{uni}^M) is the regime in which the unified R&D subsidy (s_{uni}) is set to maximise EU welfare, and the East also sets the cooperative FDI subsidy (s_{uni}^M). *** The unified all (s_{uni}), is the benchmark unified subsidy in which the R&D and the FDI policies are bundled, ($s^E = s^W = s^M = s_{uni}$), and set to maximise EU welfare.

C.1 Alternative assets allocation

In the alternative specification we assume that Western consumers finance both the innovative R&D in the West and the adaptive R&D for the transfer of production to the East, and thus receive, in the form of dividends, the profits of firms operating in the West and increased profits from the multinational operations in the East. The East, on the other hand, finances only the innovative R&D of the local firms and thus receive the profits of the eastern leaders.

Therefore, using the free entry conditions, we can derive the total per-capita assets of the two regions as

$$\begin{aligned}
\mathcal{A}^W &= \int_{\omega^W} \frac{v^W(\omega)}{L^W(t)} d\omega + \int_{\omega^M} \frac{v^M(\omega)}{L^W(t)} d\omega = \int_{\omega^W + \omega^M} \frac{v^W(\omega)}{L^W(t)} d\omega + \int_{\omega^M} \frac{(v^M(\omega) - v^W(\omega))}{L^W(t)} d\omega \\
&= \int_{\omega^W + \omega^M} (1 - s^W) \frac{2\kappa}{\gamma^W \ell^W} \frac{q(\omega, t)}{Q(t)} d\omega + \int_{\omega^M} (1 - s^E) w^E \frac{2\kappa}{\gamma^M \ell^W} \frac{q(\omega, t)}{Q(t)} d\omega \\
&= (1 - s^W) \frac{2\kappa}{\gamma^W \ell^W} (q^W(t) + q^M(t)) + (1 - s^E) w^E \frac{2\kappa}{\gamma^M \ell^W} q^M(t), \tag{63}
\end{aligned}$$

in the West, and similarly for the East

$$\begin{aligned}
\mathcal{A}^E &= \int_{\omega^E} \frac{v^E}{L^E(t)}(\omega) d\omega \\
&= \int_{\omega^E} (1 - s^E) w^E \frac{2\kappa}{\gamma^E (1 - \ell^W)} \frac{q(\omega, t)}{Q^{E+M}(t)} d\omega \\
&= (1 - s^E) w^E \frac{2\kappa}{\gamma^E (1 - \ell^W)} \frac{q^E(t)}{q^E(t) + q^M(t)}. \tag{64}
\end{aligned}$$

Substituting the two conditions above in the expressions for per-capita consumer expenditure we obtain the steady-state per-capita consumption as

$$\begin{aligned}
c^W &= 1 + (\rho - n) \left((1 - s^W) \frac{2\kappa}{\gamma^W \ell^W} (q^W(t) + q^M(t)) + (1 - s^E) w^E \frac{2\kappa}{\gamma^M \ell^W} q^M(t) \right) \\
&\quad - \int_{\omega} s^W I^W \frac{2\kappa}{\gamma^W \ell^W} \frac{q(\omega, t)}{Q(t)} d\omega \\
&= 1 + (\rho - n) (1 - s^W) \frac{2\kappa}{\ell^W} \left(\frac{q^W(t) + q^M(t)}{\gamma^W} + w^E \frac{q^M(t)}{\gamma^M} \right) - s^W I^W \frac{2\kappa}{\gamma^W \ell^W}, \tag{65}
\end{aligned}$$

for the West, and similarly for the East

$$\begin{aligned}
c^E &= w^E \left(1 + (\rho - n) (1 - s^E) \frac{2\kappa}{\gamma^E (1 - \ell^W)} \frac{q^E(t)}{q^E(t) + q^M(t)} \right. \\
&\quad \left. - \int_{\omega^M + \omega^E} s^E I^E \frac{2\kappa}{\gamma^E (1 - \ell^W)} \frac{q(\omega, t)}{Q^{M+E}(t)} d\omega - \int_{\omega^W} s^E I^M \frac{2\kappa}{\gamma^M (1 - \ell^W)} \frac{q(\omega, t)}{Q(t)} d\omega \right) \\
&= w^E \left(1 + (\rho - n) (1 - s^E) \frac{2\kappa}{\gamma^E (1 - \ell^W)} \frac{q^E(t)}{q^E(t) + q^M(t)} - s^E \frac{2\kappa}{1 - \ell^W} \left[\frac{I^E}{\gamma^E} + \frac{I^M}{\gamma^M} q^W(t) \right] \right). \tag{66}
\end{aligned}$$

Compared to the main specification in the text, the difference in the global distribution of assets

comes from a different allocation of the additional assets value created in the sectors that transfer production from the West to the East. This is represented by the last term in the expression for eastern assets in the main specification (equation 45), which now becomes a part of western assets in the alternative specification with western financing of the transfer (last term in the expression for western assets, equation 63). This change has an effect on the consumption expenditure channel in our welfare analysis, but has no implications on the change in total welfare of each region with an increase in subsidies.

For illustration, we present the numerical simulation of the Western R&D subsidy effects in Figures C.1 and C.2. An increase in Western subsidy produces the same effects on the innovation rates and geographical distribution of sectoral leadership as in the main specification. Due to a strong increase in innovation in all sectors in the West the growth component of welfare is higher. In the West, consumption expenditure now increases with subsidies due to additional assets value coming from the increased production transfer, now financed and appropriated by the West. However, the effect is not strong enough to compensate for the higher tax burden of raised subsidies and the consumption component of the welfare falls. On the other hand, the price index falls with more production done by the multinational firms in the East which contributes positively to both regions' welfare. As before, the total welfare in the West rises.

In the East, the value of assets falls with Western R&D subsidy, not only due to a loss in sectoral leadership, but also due to the loss of additional sectoral profits of multinational subsidiaries which are now appropriated by the West. The consumption expenditure channel is reduced, but this negative effect is compensated for by the price index channel, and the rise in the global growth rate. Therefore, the welfare in the East increases.

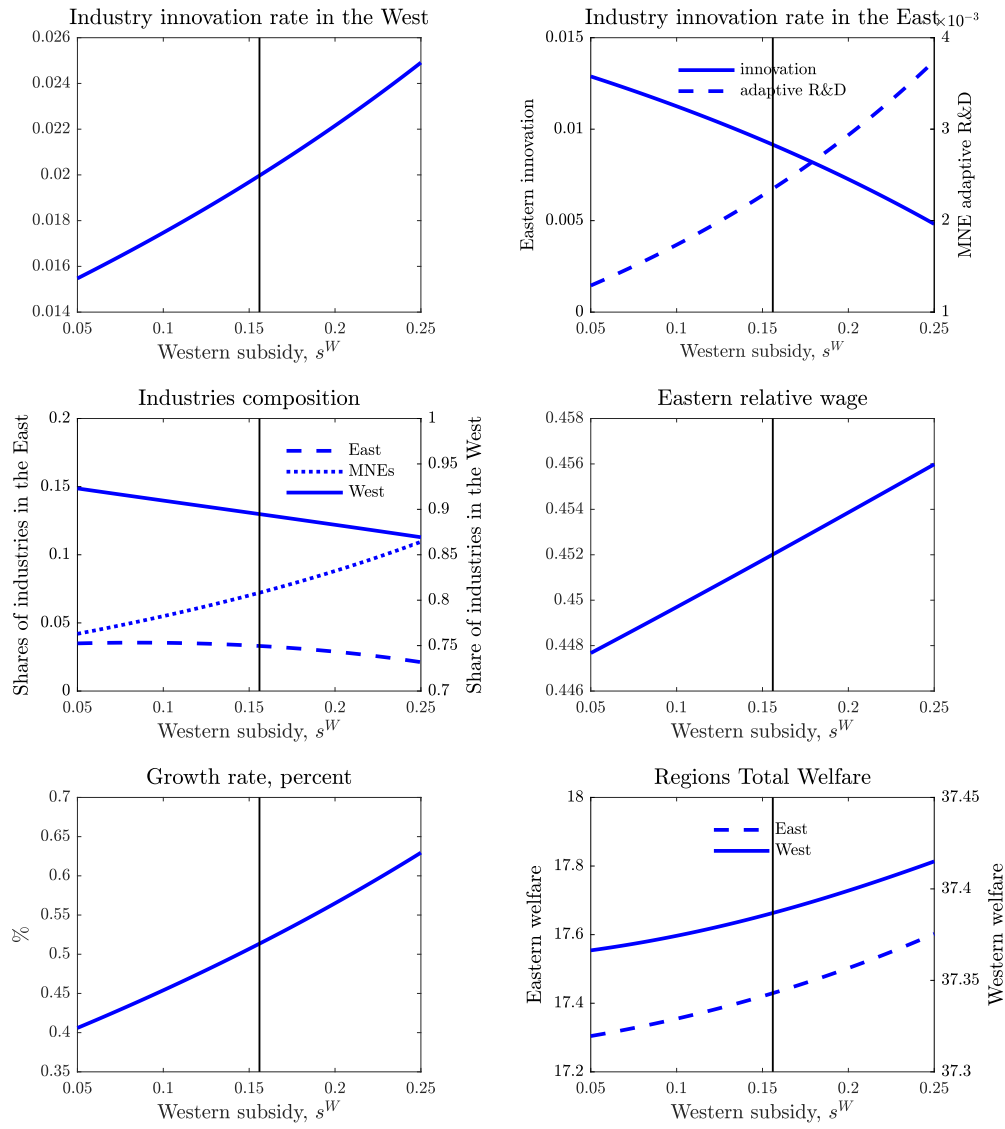


Figure C.1: Increase in Western subsidy under alternative assets allocation

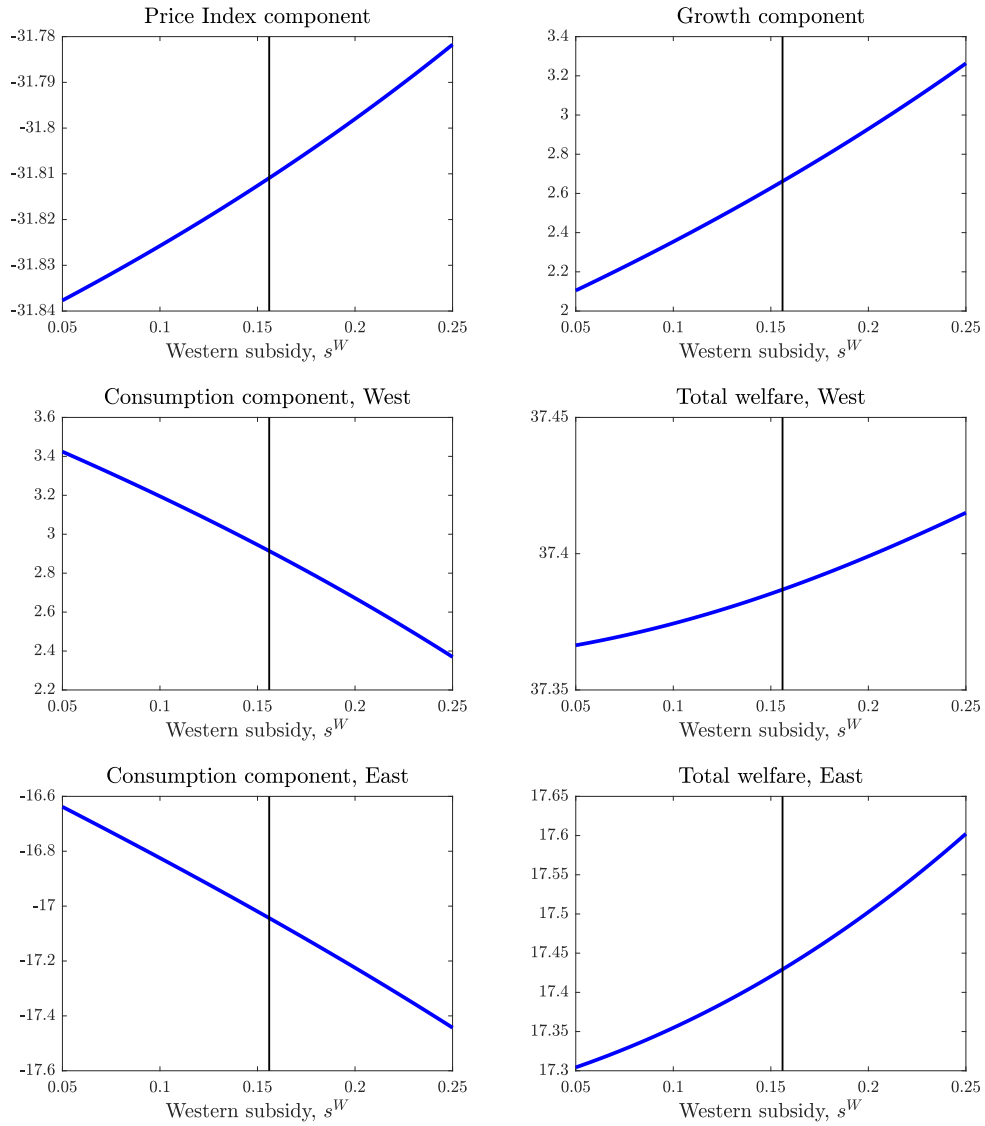


Figure C.2: Increase in Western subsidy under alternative assets allocation, welfare components

Table C.4: The effect of cooperation under alternative assets allocation

	s^W	s^E	W^W	W^E	W^{EU}	<i>growth</i>			
Observed (s_n^W, s_n^E)	0.1560	0.1420	37.3868	17.4294	54.8162	0.5135			
Nash (s_n^W, s_n^E)	0.5141	0.3504	37.4835	19.3583	56.8418	1.1286			
Unified (s_{uni})	0.7789	0.7789	37.4562	20.1924	57.6486	2.3211			
No subsidies ($s^W = s^E = 0$)	0	0	37.3970	17.2292	54.6262	0.3650			
Welfare gains									
Unified vs. no subsidy			0.0026	0.1301	0.1327				
Unified vs. observed			0.0030	0.1214	0.1244				
Unified vs. Nash			-0.0012	0.0366	0.0354				
International business stealing			-0.2779	-0.2401	-0.5180				
Static consumer surplus			0.0052	0.0052	0.0104				
Growth			0.2715	0.2715	0.5430				
Convergence	w^E/w^W	A^E/A^W	c^E/c^W	ω^E	ω^W	ω^M	I^E	I^W	I^M
Nash	0.4579	0.0052	0.4511	0.0014	0.8421	0.1565	0.0004	0.0453	0.0085
Unified	0.4389	0.1888	0.4685	0.0350	0.9046	0.0604	0.0519	0.0896	0.0095

Table C.5: Welfare gains of different policy regimes in alternative assets allocation scenario

Welfare gains	(1) Cooperative two instruments	(2) Unified one instrument	(3) Cooperative two instruments	(4) Cooperative FDI only	(5) Cooperative R&D only (3)-(4)
West	-0.0026	-0.0012	0.0030	-0.0022	0.0052
International business stealing	-0.2558	-0.2779	-0.4527	-0.0020	-0.4507
Static consumer surplus	-0.0023	0.0052	-0.0010	-0.0046	0.0036
Growth	0.2554	0.2715	0.4567	0.0044	0.4523
East	0.0533	0.0366	0.1601	0.0353	0.1248
International business stealing	-0.1998	-0.2401	-0.2956	0.0354	-0.3310
Consumer surplus	-0.0023	0.0052	-0.0010	-0.0046	0.0036
Growth	0.2554	0.2715	0.4567	0.0044	0.4523
EU	0.0507	0.0354	0.1631	0.0331	0.1300
International business stealing	-0.4556	-0.5180	-0.7483	0.0334	-0.7817
Static consumer surplus	-0.0045	0.0104	-0.0020	-0.0046	0.0026
Growth	0.5107	0.5430	0.9134	0.0089	0.9045

Notes. Welfare gains are in consumption equivalence, computed as described in section 4.3.2. Column (1) presents the gains from optimal cooperative unified R&D subsidy and optimal cooperative FDI subsidy (s_{uni}, s_{uni}^M), relative to the Nash scenario, where s_n^W maximises W welfare and s_n^E and s_n^M maximise E welfare. Column (2) reports the benchmark results in Table 4, i.e. gains of cooperation when R&D and FDI policy instruments are bundled. The following columns present the gains relative to the no subsidies regime ($s^W = s^E = s^M = 0$) of the following regimes: (3) Optimal unified R&D subsidy and optimal cooperative (set to maximise EU welfare) FDI subsidy (s_{uni}, s_{uni}^M), (4) optimal cooperative FDI subsidy (s_{uni}^M) with no R&D policy ($s^W = s^E = 0$), and (5) as the difference between (3) and (4) isolating the gains from optimal R&D policy only.

Table C.6: Unbundling FDI (s^M) and R&D (s^W, s^E) policy instruments in the alternative assets allocation scenario

	s^W	s^E	s^M	W^W	W^E	W^{EU}	<i>growth</i>		
Benchmark FDI subsidy									
Observed R&D subsidies (s_n^W, s_n^E)	0.1560	0.1420	0.1420	37.3868	17.4294	54.8162	0.5135		
Nash R&D subsidies (s_n^W, s_n^E)	0.5460	0.3748	0.1420	37.5100	19.5704	57.0804	1.2062		
No R&D subsidies ($s^W = s^E = 0$)	0	0	0.1420	37.3920	17.3391	54.7311	0.3672		
Optimal FDI subsidy									
Observed R&D subsidies (s_n^W, s_n^E)	0.1560	0.1420	1	37.3444	18.1926	55.5370	0.5361		
Nash subsidies (s_n^W, s_n^E, s_n^M)*	0.5628	0.3916	0	37.5256	19.6618	57.1873	1.2493		
Unified R&D subsidies (s_{uni})**	0.7793	0.7793	1	37.4655	20.8752	58.3407	2.3707		
No R&D subsidies ($s^W = s^E = 0$)	0	0	1	37.3477	18.0324	55.3801	0.3845		
Welfare gains									
Unified R&D subsidies vs. Nash				-0.0026	0.0533	0.0507			
International business stealing				-0.2558	-0.1998	-0.4556			
Consumer surplus				-0.0023	-0.0023	-0.0045			
Growth				0.2554	0.2554	0.5107			
Convergence	w^E/w^W	$\mathcal{A}^E/\mathcal{A}^W$	c^E/c^W	ω^E	ω^W	ω^M	I^E	I^W	I^M
Nash	0.4407	0.0044	0.4563	0.0011	0.8605	0.1385	0.0004	0.0502	0.0081
Unified R&D subsidies	0.4654	0.1886	0.4826	0.0432	0.8751	0.0817	0.0481	0.0910	0.0130
Welfare gains									
Unified R&D subsidies vs. Unified all***				0.0004	0.0300	0.0304			
International business stealing				-0.0067	0.0229	0.0161			
Consumer surplus				-0.0043	-0.0043	-0.0085			
Growth				0.0114	0.0114	0.0228			
Convergence	w^E/w^W	$\mathcal{A}^E/\mathcal{A}^W$	c^E/c^W	ω^E	ω^W	ω^M	I^E	I^W	I^M
Unified all subsidies	0.4389	0.1888	0.4685	0.0350	0.9046	0.0604	0.0519	0.0896	0.0095
Unified R&D subsidies	0.4654	0.1886	0.4826	0.0432	0.8751	0.0817	0.0481	0.0910	0.0130

* (s_n^W, s_n^E, s_n^M) regime in which West and East are maximizing own country's welfare by setting the non-cooperative R&D subsidies (s_n^W, s_n^E), while East also sets the non-cooperative FDI subsidy (s_n^M)

** (s_{uni}, s_{uni}^M) regime in which West and East are maximizing the total EU welfare by setting the unified cooperative R&D subsidy (s_{uni}), while East also sets the cooperative FDI subsidy (s_{uni}^M)

*** (s_{uni}) regime in which the R&D and the FDI policies are bundled, West and East are maximizing the total EU welfare by setting the unified cooperative subsidy (s_{uni}) applying to both R&D and FDI policies.

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