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R&D offshoring and home industry productivity

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Abstract

Offshoring research and development (R&D) commonly invokes concerns regarding the loss of high value jobs and a hollowing out of technological capabilities, but it can also benefit domestic firms by enabling them to tap into the global technological frontier. We study the effect of R&D offshoring on industrial productivity in the home country using industry-level data for 18 OECD countries over a 26-year period. Simultaneity is addressed by using foreign tax policy as an instrument for offshored R&D. Our results show that R&D offshoring contributes positively to productivity in the home country, irrespective of the host country destination.

JEL classifications: O25, O33, O47, L6

Keywords: R&D offshoring, globalization, productivity, foreign R&D

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Introduction

This article investigates the impact of research and development (R&D) offshoring on industrial productivity in the home country and considers factors which may condition the effect. Globalised technology sourcing is a defining feature of innovation systems in the 21st century. By 2008, US-owned manufacturing companies performed nearly 20 percent of their total R&D outside the United States (NSF 2010). The extent of R&D offshoring by several European countries including Switzerland, Sweden and Germany appears to be even greater (European Commission 2012). The growth in R&D offshoring has long been regarded as a worrisome development for technologically advanced nations in light of the central role of R&D in driving productivity and economic growth (Mansfield *et al*. 1979; Lall 1979; Dunning 1994). Governments are increasingly inclined to offer inducements in order to ensure that 'national' firms maintain R&D activities in their historical home country.

Recent evidence has shown that firms can generate private benefits from offshoring R&D. By tapping into the globally disparate technological frontier firms can enhance their productivity and market position (Cantwell 1995). For instance, Samsung's R&D outpost in Silicon Valley is credited with playing a vital role in the company's eventual dominance in SDRAM technologies (Kim 1997). Analysis of firm-level data for firms based in the UK and Germany have shown that offshoring R&D to the United States provides a means to tap into technological spillovers and enhance performance (Griffith *et al.* 2006; Harhoff *et al.* 2012).

Notwithstanding the evidence regarding benefits to the offshoring firms themselves, the overall impact on the home country is not yet clear. The important role of Samsung in Korean economic development suggests that impacts can potentially be substantial, but to what extent is this example an exception rather than a rule? Of concern is the loss of 'scientist-to-scientist' spillovers, which are thought to occur at the location in which R&D is performed. Equally importantly, benefits associated with offshored R&D are expected to be dispersed across the company's global operations; there is no guarantee that a substantive share will be captured by operations in the home country. Additionally, benefits may be muted in the case of home countries at the technological frontier because the relative technological capacity of the home country determines scope for learning (Song and Shin 2008; Song *et al.* 2011). The extent to which benefits may hinge on offshoring to a frontier economy has not been subject to direct empirical scrutiny though Griffith *et al.* (2006) note in passing that they are unable to confirm a positive impact from offshoring to countries other than to the United States. This is cause for concern to policy makers in the United States, which is the home country to firms engaged the most in R&D offshoring.

We study the effect of R&D offshoring on industrial productivity in the home country using new patent-based indicators of R&D offshoring linked to 2-digit manufacturing production data from 18 OECD countries between 1981 and 2007. Our industry-level approach provides a global and long-term view and avoids many of the sampling and selection issues inherent in firm level studies. It captures the net effect on local industry taking into account spillover effects which are an important component of the policy puzzle. After all, we expect firms to derive private benefit from their own offshoring decisions, at least on average.

We also extend the literature by tackling the difficult issue of simultaneity between productivity and offshoring. Simultaneity arises because home country technological capacity determines the existence of leading multinational enterprises (MNEs) as well as their capacity to manage and benefit from globally dispersed R&D assets (Vernon 1966; Patel and Pavitt 1988, 1991; Le Bas and Sierra 2002; Song and Shin 2008; Song *et al.* 2011). To address the issue of simultaneity we use country-industry specific measures of R&D tax policy as an instrument for R&D offshoring activity. R&D tax policy provides a promising instrument since foreign tax policy is exogenous to domestic productivity; it is difficult to imagine a mechanism through which R&D

specific tax incentives in the UK will affect industrial productivity in the USA except via their influence on the distribution of company R&D between the two countries. R&D tax incentives have been shown to have a significant influence on R&D location decisions (Bloom and Griffith 2001; Wilson 2009). The results are robust to We also consider a conventional application of systems GMM (Blundell and Bond 1998).

Our results show that R&D offshoring contributes positively to productivity in the home country, irrespective of the host country destination. However, we report evidence suggesting that the benefits hinge on the nature of offshoring activities, with technology-seeking offshored R&D bringing the most benefits and market-seeking offshored R&D potentially reducing productivity.

Theoretical framework

In light of the ongoing growth in R&D offshoring it would be difficult to argue that firms are not generating private benefits. Scholars have long recognized that offshoring provides a critical mechanism to tap into the globally disparate technological frontier (Ronstadt 1978; Cantwell 1995). Offshoring provides a means for firms to procure technologies not necessarily available in the home market. All the 25 most patent intensive US companies engage perform some R&D abroad – and every one of the acquire patents from abroad in technology areas that they do not acquire from local R&D (derived from USPTO).

Our research question deals with not just the magnitude of benefits of R&D offshoring but also the distribution of those benefits. Benefits from R&D activity accrue to the investing firm and can also spill over to neighboring firms. In this section we begin by considering each of these in turn, with a view to articulating the mechanism through which R&D offshoring impacts productivity in the home country. Factors that may mitigate or condition the effect are then discussed.

Some of the value generated by new technology will be captured by the plant where the technology is implemented; this may be the country in which the research was conducted, in the firm's home-base, or in a third country in which the firm has production assets. Value is also captured at other points along the firm's value chain. The share of value captured by manufacturing activities *per se* in global value chains is typically low and appears to be falling (Bartlett and Ghoshal 2000; Ali-Yrkkö and Rouvinen 2015). Value also permeates upstream and downstream global value chains, with a large share of value added captured by operations in the home country, including headquarter operations as well as niche high value contributions to production activities (Ali-Yrkkö and Rouvinen 2015).

It is well understood that firms generally do not capture all benefits associated with R&D investment. Benefits also spill over to neighboring firms and these spillovers also contribute to the geographic distribution of benefits of offshored R&D. Spillovers can arise at three loci of the innovation process: invention, production and ownership. Those at the invention stage are well understood and involve the formal and informal exchange of information between scientists. Although the literature emphasises that knowledge spillovers are highly localised (Jaffe *et al.* 1993), spillovers from offshored R&D to other firms in the home country have also been documented (Criscuolo 2009). Spillovers associated with the production processes where technologies are implemented are similarly well understood. Like internalised benefits, they are diffused along the production chain and work through interactions with suppliers, demonstration effects and engineering and management consultancy. Firms in the home country can benefit from the offshoring activities of their compatriots via demonstration effects or through supply-chain-mediated technology upgrading (Porter 1990). Trade in intermediate goods is also an important transmission mechanism for productivity gains at the production stage (Griliches 1979). Finally, technology owners in the home country hold managerial and strategic insights that can benefit local upstream and downstream actors.

Not all R&D offshoring is expected to bring equal benefits to the home country. For instance, R&D offshoring that is intended primarily to adapt products for specific local markets (known as 'market-seeking' R&D) is unlikely to generate extensive spillovers to the firm's home country (*cf.* Arvanitis and Hollenstein 2011). Scope for learning can also influence firm level benefits (Song and Shin 2008; Song *et al.* 2011). Recent research has emphasised the importance of offshoring R&D to technological leaders and the United States in particular (Griffith *et al.* 2006; Harhoff *et al.* 2014). Although the United States is certainly a leader by many aggregate measures, the existence of centers of excellence around specific technology areas and niche technical and scientific skills in other parts of the world scarcely requires argument. Global technology strategy provides a mechanism for sourcing the best technology from an increasingly globally disparate frontier. If informed firms act rationally in choosing the location of offshored R&D we should expect all offshored R&D investments to generate returns commensurate with the risk and costs they involve.

The distribution of firms' ability to benefit from R&D offshoring gives rise to the important consideration of simultaneity between offshoring and performance which has, to date, largely escaped the modeling effort of empirical economists (Griffith *et al.* 2006:1873). Leading MNEs have most to gain from R&D offshoring because of their superior absorptive capacity (Song and Shin 2008). Leading firms also possess organization capabilities that allow them to manage the complex process of R&D offshoring, so that they are the most likely to engage in that activity. Insights from management studies similarly suggest that R&D offshoring is the privilege of the fittest (Patel and Vega 1999; Le Bas and Sierra 2002). We tackle the problem of simultaneity using instrumental variables which is explained further in the next section.

Measuring home and offshored R&D

Ideally we would observe industry level R&D expenditures by country of funding (the firms home base) and country of performance (the host country). Unfortunately, statistical agencies do not collect such data systematically. We resort to patent data, which provide an indicator of both home and offshored R&D (Guellec and van Pottlesberghe 2001; OECD 2009; Picci 2010; Thomson 2013). Home R&D is captured with patents that have both domestic applicants and inventors. A patent that derives from offshored R&D is a patent with a domestic applicant and a foreign inventor. The applicant's address provides an indicator of the MNEs home country and inventor's country of residence indicates the MNEs offshoring location.

In most cases, owners of valuable technology want protection from would-be imitators in many countries. To achieve this, they must file patent applications to the intellectual property office in each country they want protection. Patents are generally filed in production centers, major markets, and the location of competitor firms. The first filing protecting an invention is called a priority patent application. Subsequent applications protecting the same invention in other jurisdictions are called second filings. Only priority patent applications are included in our measure since second filings are not indicative of additional R&D activity.

The measure of offshoring is calculated using the universe of inventor-applicant pairs (including 'inventor countries' that are not in the OECD). Multi-inventor or multi-applicant patents that span more than one country are fractionally counted. The data come from the European Patent Office (EPO) Worldwide Patent Statistical Database (PATSTAT). The algorithm used to identify priority filings and to fill in missing data on applicant and inventor country of residence is discussed in de Rassenfosse *et al.* (2013). Figure 1 shows that the worldwide proportion of ‘offshored patents’ has grown, from 3 percent in the early 1980s to more than 10 percent in the late 2000s.

[Figure 1 about here]

We allocate patents across industrial sectors using the International Patent Classification (IPC)–industry concordance table developed by Schmoch *et al.* (2003).[1] The concordance table is derived from a complete enumeration of the patenting activity in technology-based fields of more than 3,000 firms that are classified by ISIC industrial sector. Some measurement error is inevitable in such concordance procedure, though we expect this measurement error to be largely stable over time meaning it can be accommodated in the econometric model in the same manner as other time invariant heterogeneity.

Our patent data are unique because they provide a systematic, comprehensive and global view, though naturally, they capture the phenomenon of interest with some noise. We take a number of steps to increase confidence that our patent-based indicators are representative of R&D activities. We discuss key aspects next.

Market-seeking R&D offshoring is anticipated to generate fewer benefits to the firms’ home country. Our analysis focuses on technology-seeking R&D, which is identified by those patents which are filed in the home country. We argue that one can use filing behavior to identify technology- versus market-seeking R&D offshoring. Technology-seeking R&D is targeted at developing novel technologies that will be used in the company’s global operations such that there are strong incentives to seek protection in the home country. Market-seeking offshored R&D is directed towards producing a technology for, or adapting it to, the local market. Since

[1] The IPC is a hierarchical patent classification system used in over 100 countries to classify the content of patents in the technology area to which they pertain.

technology generated via market-seeking R&D offshoring has relatively market-specific usefulness there is limited impetus for the inventing firm to file for patent protection in the home country.[2]

By focusing on patents that are *filed* in the home (applicant) country we also largely avoid measurement error associated with 'IP migration', which is where the applicant address is chosen purely for tax minimization purposes. There is no incentive for firms to file for patent protection in the Cayman Islands even if they allocates ownership to their Cayman Island subsidiary for the purpose of tax minimization.[3] Our sample avoids many of policies which generate high powered incentives to undertake IP migration. Well-known tax havens such as the Cayman Islands are not included in our sample and the period of analysis pre-dates the 'patent box' policies implemented in the Netherlands, Belgium, Luxembourg, and Spain after 2007. For the countries in our sample, aggregate patterns of patent assignment are not consistent with what would be predicted by tax minimization. For example, in low-taxing Ireland more patents invented by residents of Ireland are assigned to foreign firms than foreign invented patents are assigned to Irish affiliates—precisely the opposite of what tax minimizing behavior would predict. While we see no strong *a priori* reason to suspect that any measurement error arising out of IP migration, should it exist, should be systematically related to changes in productivity at the industry level we consider augmented empirical specifications in an effort to directly control for corporate income tax rate in the home country as part of our robustness checking.

[Table 1 – about here]

[2] Note that by construction we filter out R&D activities that are both invented by and also assigned to a foreign affiliate.

[3] Indeed, allocation/transfer of ownership for tax purposes mainly takes the form of intra-company transfer that needs not be reported to the patent office in order to be effective.

Table 1 shows that there were four million priority patent applications filed worldwide in the period between 1980 to 2007, among which 182 thousand (4 per cent) are the result of R&D offshoring. Restricting the count to patent applications filed in at least two jurisdictions (thus filtering out a large number of low-value patents) leads to a worldwide count of 1.6 million patent applications, of which approximately 8 per cent result from R&D offshoring.

We validate our measure of offshored R&D by considering the relationship between patents assigned to foreign entities and the international flows of finance for the purposes of R&D. Data on bilateral R&D flows do not exist, however total R&D financed from abroad aggregated across partner countries are collected by national statistics agencies by way of firm level survey (effectively aggregate R&D 'onshoring'). The measure is expected to comprise primarily technology seeking R&D activities. The criteria for recording R&D by source of funds in the Frascati manual stipulates that "there must be a direct transfer of resources [and] the transfer must be both intended and used for the performance of R&D" (OECD 2002:114). It does not include foreign sourced loans or other general capital raising or general transfers from the parent firm. It also does not include R&D performed by MNE affiliates and financed through retained earnings.

Table 2 reports a series of regression results aimed at testing this relationship. The dependent variable is the lagged amount of R&D financed from abroad (in million 2005 US PPPs) at the country level in panel A and at the country-industry level in panel B. Pooled cross-section and fixed effect estimates suggest a strong relationship between the patent indicator and the relevant R&D flows, even when adding additional lags to the specification. The results show that the production of patents with foreign applicant is strongly determined by foreign financed R&D. They provide further confidence in the validity of our patent based measure of offshored R&D.

[Table 2 – about here]

Statistical approach

We study the productivity effect of R&D offshoring using a standard Cobb-Douglas production function with labor (denoted by L), fixed capital (denoted by K) and technology (denoted by A^*).

$$Y = K^{\alpha} L^{1-\alpha} (A^*)^{\gamma} \qquad (1)$$

We treat the distinction between technology from the home country and from abroad in an analogous manner to the treatment of basic and applied R&D proposed by Griliches (1986), allowing for the possibility that technology stock derived from offshored R&D (denoted by A_F) attracts a δ premium (or discount) relative to technology stock derived from home R&D (which is denoted by A_H).[4] That is:

$$A^* = A_H + (1+\delta) A_F = A_T(1+\delta S) \qquad (2)$$

where $S = \frac{A_F}{A}$ is the share of technology stock generated via offshoring of the total $A = A_H + A_F$.

Transforming equation (1) gives the canonical for of our estimating equation:[5]

$$\ln\left(\frac{Y}{L}\right) \cong \alpha \ln\left(\frac{K}{L}\right) + \gamma \ln A + \gamma\delta \frac{A_F}{A} \qquad (3)$$

To incorporate the dynamic evolution of productivity, we augment equation (3) with a lagged dependent variable giving a baseline estimation equation as:

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[4] Note that treating foreign R&D as a distinct complementary input (as in $Y = K^{\alpha} L^{1-\alpha} A^{\gamma} A^{\gamma'}$ implausibly implies that industries which undertake no offshoring can generate no output.

[5] We considered an alternative approach based on first estimating a growth equation to derive an estimate of industry level total factor productivity, which is then modelled in an analogous manner. The results were quantitatively similar. We thank Jacques Mairesse for this suggestion.

$$\ln\left(\frac{Y}{L}\right)_{ijt} = \beta \ln\left(\frac{Y}{L}\right)_{ijt-1} + \alpha \ln\left(\frac{K}{L}\right)_{ijt} + \gamma \ln A_{ijt} + \gamma\delta\left(\frac{A_F}{A}\right)_{ijt} + \lambda_t + \mu_{ij} + \varepsilon_{ijt} \quad (3)$$

where the index i denotes the country, j the industry and t the year. The error structure is assumed to comprise country-industry fixed effects as well as year effects.

We model output of manufacturing sectors at the 2-digit level of the International Standard Industrial Classification (ISIC Revision 3, codes 15-36) in 18 countries over the period from 1980 to 2007. Data on value added, capital stock and employment are compiled from the OECD Structural Analysis Database (OECD 2011). Royalties are included in industry value added regardless of whether technology users in the home country or abroad pay the royalties.[6] Table 3 reports summary statistics for measures used in the regression analysis.

[Table 3 – about here]

The industry level approach suits well our purpose of providing a global and long-term view. In addition, it avoids selection issues endemic in firm-level studies arising out of the role of productivity in entry and exit decisions (see, *e.g.*, Olley and Pakes 1996; Breunig and Wong 2008). However, we are mindful of the potential endogeneity associated with the correlation of input choices with productivity shocks and the related concern regarding the persistence of productivity variables over time. Dynamic panel bias that arises due to correlation between the lagged dependent variable is also of concern (Nickell 1981). To address dynamic panel bias we estimate equation (3) using systems GMM (Blundell and Bond 1998). The GMM estimates reported use the asymptotically efficient two-step procedure and apply Windmeijer's (2005) correction to the standard errors.

[6] In the standard national accounts framework, royalties are counted as sales if the buyer is at home or as a service export if the buyer is foreign.

As already discussed, accounting for potential simultaneity between productivity and R&D offshoring is fundamental to any attribution of causality. We consider a number of approaches to accommodating this issue. First, we consider an instrumental variable approach using a measure of the tax treatment of R&D in the home country and in potential offshore R&D host countries. We also consider a more conventional route to disentangle the causal impacts using systems GMM by instrumenting offshored share of technology stock in a manner analogous to the autoregressive term. We elaborate the instrumental variable approach below.

The appropriateness and validity of tax policy as an instrument is well supported. The *a priori* case that foreign tax policy is exogenous to domestic productivity is sound. It is difficult to imagine a mechanism through which R&D specific tax incentives in the UK will affect industrial productivity in the USA except via their influence on the distribution of company R&D between the two countries. Evidence suggests R&D tax policy influences firms' R&D location decisions (Hines 1993; Bloom and Griffith 2001; Wilson 2009). We expect tax policy to primarily influence the intensive margin (rather than extensive) for technology-seeking type R&D offshoring; we argue that the margin that is amenable to the influence of fiscal incentives is of greatest interest to policy. Validity of the instrument also requires independence with the outcome variable, namely productivity.

Data used to measure R&D tax policy are adapted from Thomson (*forthcoming*). The measure is based on the standard adaptation of Jorgenson's (1963) 'user cost of capital' first proposed by McFetridge and Warda (1983) and subsequently developed by Bloom *et al.* (2002), Wilson (2009) and others. The measure, referred to as the 'tax-price of R&D', reflects the breakeven benefit-cost ratio for a representative firms' marginal R&D investment to be profitable after tax taking into account any reductions to corporate tax liabilities associated with each dollar invested in R&D. Our country-industry specific policy measure incorporates crosscountry variation in tax treatment of different R&D expenditure types (*e.g.*, labor and capital) as well as inter-industry variation in mix of expenditures by type. To measure the effective tax price of offshored R&D for each country we use the average tax price across potential offshoring locations (i.e., all other countries in the sample). Tax policy data are only available for OECD member states so non-OECD countries are not included in this calculation. This limitation has negligible impact on the measured weighted average offshored tax price as only a small fraction of patents are attributed to inventors who are residents of countries for which we do not have tax price information (see also Kumar 2001; Thomson 2013).

Does offshoring affect home country productivity?

Table 4 depicts the main regression results. Column (1) presents a baseline fixed effects estimate. Columns (2) and (3) show the instrumental variable model. Results of the first stage regression, which models the determinants of the share of technology stock derived from offshoring, are presented in column (3) and are of considerable interest in their own right. These results are consistent with the view that the location of R&D is amenable to the influence of tax subsidies at the margin. The coefficient associated with the average R&D tax price abroad is negative and significant, showing that a lower tax price abroad is correlated with a greater share of all technology stock being sourced from abroad. Correspondingly, domestic (home country) tax price is found to be positively related to the share of technology sourced from abroad, which implies that the higher the local tax price the more technology is sourced from offshore locations. The second stage results are presented in column (2). A Durbin-Wu-Hausman test supports the theoretical prediction that offshoring is likely to be endogenous (p=0.001). The coefficient associated with the offshoring share variable in the second stage equation is 1.478. These estimates may be affected by the issues of dynamic panel bias and the possibility that input choice (physical capital and technology stock) are endogenous to output.

Column (4) and (5) of Table 4 present GMM estimates. Both capital stock per worker and technology stock per worker are identified via standard systems GMM instruments (differences in the level equation, and levels in the difference equation). In column (5) the share of patent stock generated through offshoring is also identified using the standard systems GMM approach. Instrument matrix for column (4) includes foreign and domestic tax price measures in place of standard GMM instruments. As can be seen, the results do not vary greatly between the two identification approaches. The results suggest that as an industry increases the share of technology generated via offshoring from the mean of around 10 percent to 20 percent, productivity will increase by 4 percent. The implied premium associated with offshored R&D is large, though reasonably commensurate with anticipated additional costs associated with R&D offshoring versus domestic R&D. Our fundamental contribution is furnishing new evidence that the home country – not just the firm – can benefit from R&D offshoring.

Column (6) reports the first of our robustness checks whereby we augment the model with both corporate income tax rate and the local R&D tax price. The coefficients of interest are effectively unchanged which, we argue, provides further confidence that tax minimizing intellectual property migration is not unduly influencing our estimates.

[Table 4 about here]

We have argued previously that patents generated via offshored R&D but not filed in the home country are likely to represent adaptive, market-seeking R&D and are less likely to benefit the home country. Empirically testing this proposition is made complicated by the fact that the subset of patents derived from offshoring that are filed in the home country are highly correlated with total offshoring (correlation coefficient 0.94). In column (7) we report estimates of a model that includes both the share of technology stock from technology-seeking type offshoring (patents invented abroad and also filed in the home country) and the share technology stock from market-seeking type offshoring (patents invented abroad but not filed in the home country). The coefficient associated with market-seeking R&D offshoring is negative and significant. The estimate suggests that market-seeking type R&D offshoring, which results in patents that are *not* filed at home, may detract from home-base productivity. This finding supports our conjecture that filing behavior provides a valuable indicator of whether the technology benefits home country operations.

An important advantage of our industry level data is the exhaustive and global nature of the sample. It is widely considered that firms' benefits from offshoring may depend on the R&D occurring in a frontier country or perhaps even in the United States specifically. This may be cause for concern to policy makers in the United States, which is the home country to firms engaged in the most in R&D offshoring. Using our data, we are able to test the extent to which the relationship between offshoring R&D and home-base industrial productivity may be driven by offshoring to any specific country. To flush out any above average impact of any particular host country we re-estimate the model 21 times, each time calculating a modified share of technology stock sourced from offshoring with a different host country omitted. Table 5 reports estimates of the coefficient on share of technology stock from offshoring, each row reflecting a different country omitted. These results show that no one single country is driving the estimated parameter of interest. Put another way, in contrast to Griffith *et al.* (2006), we find nothing 'special' about offshoring to the United States, conditional on the outputs of the offshored R&D being filed in the applicant country (our measure of technology-seeking R&D offshoring).

[Table 5 about here]

We also considered the possibility that atypically large benefits from R&D offshoring by firms based in a specific home country may be driving the result. This may be the case if absorptive capacity that is crucial for establishing overall benefit is distributed unevenly. The second panel of Table 5 presents estimates of the same model, this time sequentially dropping a different home country for each row. The estimated coefficient appears quite stable giving no indication that the result hinges on any particular country. We also performed similar analysis using the full sample of countries but dropping one industry at a time and found no indication that the result is overtly influenced by the offshoring activities of any single industry.

Before offering concluding comments we consider the remaining limitations. First, while we provide a representative view of the average benefits reflecting the net impact on local industry, including both private and spillover benefits and losses, the industry level approach provides no new evidence on the mechanism through which offshored R&D translates into productivity improvements at home. These have been studied elsewhere and are complementary to our finding (*e.g.*, Harhoff *et al.* 2014). Direct analysis of the extent of spillovers would be worthwhile and best undertaken using firm level data. Second, we expect that, in part, our result reflects a higher cost of offshored R&D (though low value patents are filtered out). Irrespective, our results newly confirm that the home country – not just the firm –benefit from offshoring and indicate that benefits are not contingent on the specific host locations. Finally, we are keenly aware that any instrumental variable estimation is open to fundamentally untestable criticism regarding the veracity of the assumption of exogeneity. We have argued that the *a priori* case that foreign R&D tax subsidies is exogenous to domestic productivity is sound and, this appears to be borne out by standard overidentification tests, notwithstanding their inherent limitations. We are perhaps most reassured by the fact that result appears robust across two different identification strategies (IV and GMM).

Conclusion

The potential for R&D offshoring to weaken the home country technological capabilities and the loss of productivity spillovers compromising long-term growth has concerned policy makers for a long time. We have investigated this concern using new industry-level data we employed an identification strategy which accommodates the potential simultaneity between industrial performance and globalization Our results show that R&D offshoring can induce long-term productivity benefits for home-country industrial actors at large.

We find no evidence that benefits are restricted to firms offshoring to the United States—or any other host country in our sample. This supports the view that firms themselves are best placed to choose the location of R&D which will generate technological advantage and equally that the globally dispersed technology frontier is difficult to capture using aggregate national indicators. However, we find that home country benefits hinge on the nature of offshoring. Our results are consistent with the arguments made by previous scholars that the benefits of market-seeking R&D offshoring will primarily be restricted to host country markets.

Our results help to reconcile traditional fears concerning the impact of R&D offshoring on home economies with the enduringly strong economic performance of those countries most heavily engaged in the activity—the United States and Switzerland are among the handful of OECD countries that offshore more R&D than they host which are all among the most productive, technologically advanced economies (Thomson 2013). We hope that in this light, our results might give pause for thought to policy makers who may otherwise be tempted to offer inducements to curb offshoring.

Naturally, more research is needed in order to understand more detailed patterns of the geographical distribution of benefits, the extent of spillovers to other firms in the home country, and the conditions under which benefits may be enhanced. In this regard, we hope that the methodological contribution advanced in this paper may contribute to future works. Specifically, we have provided first-of-its-kind validation test of the use of patent data as a measure of R&D offshoring, making use of the origin country of applicants and inventors. Moreover, the results suggest that filing patterns provide useful information about the geography of benefit arising from patented technology and, more speculatively, a means of distinguishing between market-seeking and technology-seeking R&D activities. Future firm-level analysis exploiting information regarding filing patterns could be particularly promising in elucidating a better understanding about multinational enterprise technology strategies.

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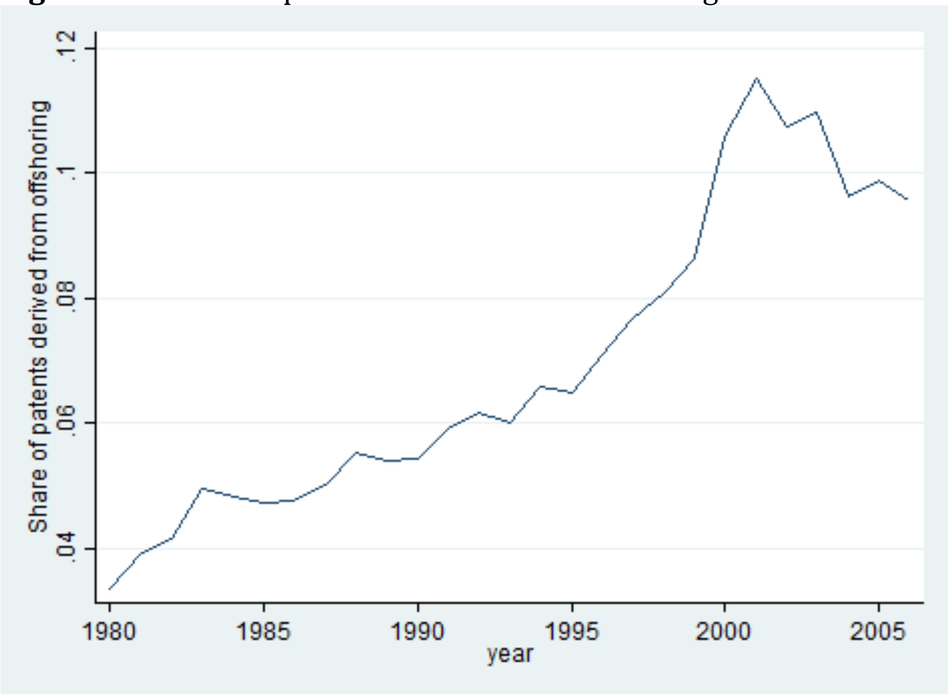
Table 1. Overall sample of patents observed

	Total	Derived from offshoring
Total priority patents	4,173,233	182,144
Filed in 2+ countries	1,631,132	133,189
Filed in 2+ countries *and* filed in the home (applicant) country	1,606,887	121,545

Notes: "derived from offshoring" identified with applicant / inventor from different countries.

Figure 1. Percent of patents derived from offshoring



Notes: filed in applicant country and family size greater than one.

Table 2. Correlation between offshored patents and R&D financed from abroad

	Panel A. Country analysis				*Panel B. Country-industry analysis*			
Method:	Pooled OLS		Fixed effect		Pooled OLS		Fixed effect	
log of foreign-financed R&D in t-1	0.625**	0.330**	0.119**	0.104**	0.335**	0.156**	0.018*	0.026*
	[0.019]	[0.062]	[0.021]	[0.028]	[0.011]	[0.032]	[0.008]	[0.010]
log of foreign-financed R&D in t-2		0.313**		0.055*		0.183**		0.005
		[0.061]		[0.027]		[0.032]		[0.011]
Constant	1.580**	1.504**	2.981**	2.898**	0.703**	1.116**	0.523**	0.815**
	[0.125]	[0.147]	[0.078]	[0.098]	[0.117]	[0.201]	[0.043]	[0.060]
Time effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	740	612	740	612	3,053	1,896	3,053	1,896
R-squared [(a)]	0.62	0.63	0.66	0.66	0.24	0.23	0.37	0.37
Number of groups	-	-	40	37	-	-	401	297

Notes: Time effects captured with decade dummies. The dependent variable is the log number of offshored patents in year *t*. Standard errors in parenthesis. **: p-value < 0.01. *: p-value < 0.05
[(a)] 'Within' R-squared reported in fixed effect specifications.

Table 3. Data Summary

Variable	Mean	Std. Dev.	Min	Max
Output per worker ('000s USD)	84.3	80.1	6.1	1236.1
Capital per worker ('000s USD; PIM w. 5% depreciation)	138.3	195.1	0.244	2375.5
Technology stock ('000s patents, PIM w. 15% depreciation)	840.7	2525.3	0.127	40436.3
Share of technology stock derived from offshoring	6.8	6.23	0.120	56.0

N = 7721

Table 4. Regression results dependent variable output per worker

VARIABLES	(1) FE	(2) FE IV	(3) IV 1st stage	(4) GMM	(5) GMM STD	(6) GMM	(7) GMM
Output per worker(logs) $_{t-1}$	0.693***	0.689***	0.00221*	0.843***	0.840***	0.832***	0.855***
	[0.00831]	[0.00851]	[0.00121]	[0.0299]	[0.0306]	[0.0299]	[0.0282]
Capital per worker(logs) $_{t-1}$	0.00988**	0.00619	0.00287***	0.00782	0.0112*	0.0157***	0.0118**
	[0.00423]	[0.00445]	[0.000618]	[0.00520]	[0.00594]	[0.00597]	[0.00559]
Technology stock (logs) $_{t-1}$	0.00794	0.0336***	-0.0209***	0.0187***	0.0147***	0.0158***	0.0118***
	[0.00782]	[0.0113]	[0.00111]	[0.00406]	[0.00383]	[0.00404]	[0.00354]
Tech. share derived from offshoring $_{t-1}$	0.240***	1.478***		0.491**	0.447***	0.419**	0.456***
	[0.0790]	[0.396]		[0.213]	[0.150]	[0.168]	[0.145]
Average tax price abroad $_{t-2}$			-0.129***				
			[0.0285]				
Local R&D tax price$_{t-2}$			0.111***			-0.0434	
			[0.00646]			[0.0432]	
Corporate income tax rate$_{t-1}$						-0.0206	
						[0.0153]	
Tech. share from offshoring not filed in applicant country $_{t-1}$							-0.799**
							[0.390]
Overidentification[a]		0.166		0.10	0.29	0.26	0.98
1st, 2nd serial correlation				0.00,0.51	0.00, 0.51	0.00, 0.51	0.00, 0.51
R-squared (within)	0.681	0.670	0.396				

Notes: N=7,721. All models control for year effects and time invariant unobserved heterogeneity at the country-industry level (444 groups). First stage Cragg-Donald F statistic for FE IV is 155. Overidentification for FE IV (column 2) presents Sargan-Hansen p-value. GMM estimates use the asymptotically efficient two-step procedure applying Windmeijer's (2005) correction to the standard errors. All right hand side variables instrumented for GMM. Instrument matrix for column (4) include foreign and domestic tax price measures in place of standard GMM instruments. Instrument count is constrained by limiting lagged instruments to t-3. Overidentification for GMM results (columns 3–7) present Hansen statistic p-value reported using xtabond2 (Roodman 2009)

Table 5. Coefficient estimates of share of technology from offshoring.

Omitted country	Tests omitting R&D offshoring to each *host* in calculation of offshoring share		Tests omitting each home country in turn		
	Coeff	s.e.	Coeff.	s.e.	Obs.
AT	0.381***	[0.109]	0.372***	[0.108]	7,766
BE	0.407***	[0.122]	0.393***	[0.110]	7,901
CA	0.376***	[0.109]	0.360***	[0.109]	7,946
CZ	0.386***	[0.108]	0.360***	[0.108]	8,096
DE	0.463***	[0.141]	0.367***	[0.109]	7,766
DK	0.390***	[0.108]	0.342***	[0.103]	7,978
ES	0.383***	[0.108]	0.403***	[0.111]	8,006
FI	0.372***	[0.110]	0.331***	[0.0986]	7,768
FR	0.461***	[0.127]	0.392***	[0.111]	8,127
GB	0.410***	[0.140]	0.378***	[0.108]	7,768
GR	0.388***	[0.108]	0.366***	[0.110]	8,129
HU	0.384***	[0.108]	0.390***	[0.112]	8,104
IE	0.385***	[0.108]	0.308***	[0.110]	8,031
IT	0.332***	[0.0962]	0.379***	[0.111]	7,796
KR	0.384***	[0.108]	0.430***	[0.110]	8,166
NL	0.417***	[0.125]	0.411***	[0.112]	7,907
NO	0.384***	[0.109]	0.354***	[0.106]	7,870
PL	0.385***	[0.108]	0.378***	[0.109]	8,078
PT	0.384***	[0.108]	0.323***	[0.0940]	8,258
SE	0.383***	[0.109]	0.379***	[0.111]	7,942
US	0.431***	[0.120]	0.390***	[0.109]	7,766

The dependent variable is output per worker. All models control for year effects and time invariant unobserved heterogeneity at the country-industry level (444 groups) [a]GMM estimates use the asymptotically efficient two-step procedure applying Windmeijer's (2005) correction to the standard errors. All right hand side variables instrumented for GMM. Instrument count is constrained by limiting lagged instruments to t-3.