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Offshoring and intellectual property rights reform☆

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ABSTRACT

This paper empirically assesses the responsiveness of US offshoring to intellectual property rights (IPR) reforms in 16 countries. We construct a measure of US offshoring at the industry level based on trade in intermediate goods, covering 23 industries for the period 1973–2006. For each industry, we differentiate between broad offshoring and intra-industry offshoring activities. We conduct a difference-in-difference analysis using the IPR reform years proposed in Branstetter et al. (2006, Quarterly Journal of Economics). We find that following IPR reform, neither broad nor intra-industry offshoring intensities change for the typical US industry at conventional levels of significance. However, high-tech (patent-sensitive) industries substantially expand their intra-industry offshoring activities, whereas low-tech (patent-insensitive) industries do not change their intra-industry offshoring activities in a statistically significant way. In addition, high-tech industries increase their broad offshoring relative to low-tech industries, but the effects are smaller and less robust than those estimated for intra-industry offshoring.

1. Introduction and literature review

Over the past three decades, global trade policies and the composition of world trade have changed dramatically. Many developing countries (the South) started raising their intellectual property rights (IPRs) protection levels and building the necessary institutional framework. This transformation received an additional push in 1995 with the signing of the TRIPS agreement (Trade Related Aspects of IPRs) under the World Trade Organization umbrella, which called for establishing at least a minimum level of IPR protection by 2006.[1]

As the global movement towards stronger IPR protection picked up pace, the issue has generated intense debate among policy makers. The proponents of TRIPS have argued that such a move would reduce the imitation risk faced by Multinational Firms (MNFs) and would encourage more technology transfer and overseas activities. Moreover, it was emphasized that a stronger IPR regime would boost innovation incentives for all firms and thus accelerate global technological progress. Meanwhile, opponents have argued that TRIPS would simply lead to a transfer of rents from the South to the developed world (the North) and hinder the South's ability to implement newly-invented Northern technologies. Thus, the prospects of increased trade and MNF activity were the central motivations for the South to raise their IPR protection and further sign on to TRIPS.

During the past three decades, North–South trade has indeed expanded dramatically. A central feature of this new era of globalization has been the rapid rise in intermediate goods trade, a phenomenon which is referred to as "offshoring". More specifically, Northern producers fragmented their production processes into a variety of intermediate goods/services, sometimes referred to as tasks,[2] and distributed them across the globe seeking the lowest-cost production locations. Production of intermediate products took place either within the boundaries of the MNFs (i.e., through foreign affiliates) or outside the boundaries (i.e., through arm's length subcontracting to Southern

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[1] See Maskus (2000) for a comprehensive overview of IPRs and globalization.

[2] See Grossman and Rossi-Hansberg (2008).

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producers or through direct purchases from Southern manufacturers). A large literature has emerged, documenting and investigating the acceleration in trade and offshoring.[3]

Interestingly, only a few studies have empirically analyzed the effects of IPR regime changes on trade and MNF activities. For example, Maskus and Penubarti (1995) and Smith (1999) examine the relationship between IPR protection and trade using US data at the industry and state levels, respectively. Branstetter et al. (2006, 2011) examine the link between IPRs and MNF activity by considering a variety of MNF measures (such as affiliate assets, affiliate R&D, affiliate overseas sales, intra-firm royalty payments and such).[4] However, none of the papers in this literature examine the issue by using an offshoring measure based on intermediate goods trade.

In this paper, our first goal is to construct a measure of US offshoring at the industry level that is mapped against the trading partners of the US and based on intermediate-goods trade. In doing so, we follow a methodology similar to the one used by Feenstra and Hanson (1996, 1999). Specifically, we define *broad offshoring* intensity for an industry-country pair as the value of intermediate goods that a US industry imports from *all* industries of a given country to produce one dollar worth of output. Following the spirit of Feenstra and Hanson (1999, p. 24), we also consider *intra-industry* offshoring intensity (also known as narrow offshoring), which measures offshoring (again understood as imported intermediate inputs) that takes place *within* the same industry. To construct the offshoring measures, we use input–output coefficients and bilateral imports at the US industry level, covering the period 1973–2006.

Our second goal is to empirically assess the responsiveness of US offshoring to IPR reforms in its trading partners. We identify the timing of IPR reforms in a total of 16 developing countries by following Branstetter et al. (2006). Our empirical strategy is to conduct a difference-in-difference analysis in the spirit of Branstetter et al. (2006, 2011). More specifically, we regress our offshoring measures on a dummy variable which takes the value of zero before reform and one in the year of reform and thereafter, controlling for industry, time, and country effects, as well as country-specific linear time trends. We further extend the analysis by sorting the industries as *high-tech* (i.e., patent sensitive) and *low-tech* (i.e., patent insensitive) in order to account for patent-sensitive industries being possibly more inclined towards offshoring after IPR reform.

We first run regressions without differentiating between industry types. These regressions imply that following IPR reform, neither broad offshoring nor intra-industry offshoring intensities change for the typical US industry at conventional levels of significance (5% or lower). We then run our regressions by distinguishing between high-tech and low-tech industries. These regressions uncover differential responses based on industry types. First, in the context of broad offshoring, we observe some evidence for increased offshoring by high-tech industries relative to low-tech industries. In particular, our baseline specification implies that high-tech industries increase their broad offshoring intensity by 31% relative to the insignificant 4% increase in low-tech industries. We should note though that the 31% estimate is only marginally significant (at 10% level) and becomes insignificant under some alternative specifications. Second, in the context of intra-industry offshoring, we now observe strong evidence for a differential response in relative terms. Our baseline specification implies that high-tech industries increase their intra-industry offshoring intensity by 128% relative to the insignificant 21.2% decrease in low-tech industries. In this case, the estimate of 128% is significant at conventional levels. Under alternative specifications, the estimates for the relative impact retain their significance albeit they lose some of their value.

We also examine the changes in offshoring intensities in high-tech industries on their own (as opposed to focusing on the changes relative to low-tech industries). This simply involves testing the null hypotheses that the sum of the estimated effects reported above is equal to zero. We cannot reject the null hypothesis for the regressions with broad offshoring as the dependent variable at conventional levels of significance. However, we can reject the null hypothesis for the regressions with intra-industry offshoring as the dependent variable. Our baseline specification implies that high-tech industries increase their intra-industry offshoring by 79.6%. As a lower bound we obtain an estimate of 38.1%. We view these estimates as implying a sizable offshoring impact because intra-industry offshoring accounts for half of all offshoring by high-tech industries to our sample of 16 countries.[5]

In addition, we conduct an event-study analysis using the methodology of Jacobson et al. (1993). Our objective is to assess whether the timing of reform coincides with the timing of changes in offshoring and also address possible concerns about endogeneity of reform. To do this, we normalize the year of IPR reform to zero and regress our offshoring measure on a set of dummies for pre- and post-reform years. We find that prior to IPR reform neither broad offshoring nor intra-industry offshoring intensities show a statistically significant upward trend. We interpret this finding as alleviating concerns about endogeneity of reform with respect to offshoring.

On the contrary, after IPR reform we observe that both broad and intra-industry offshoring intensities show an upward trend but with some lag, a reasonable result given that major institutional reform takes time to be fully enforced and implemented. In particular, the lagged effects are observed exclusively in high-tech industries. Following IPR reforms, broad offshoring intensities in high-tech industries increase relative to low-tech industries. The relative differential equals 15.3% at 2 years after reform, gradually increases with each year, and reaches 35.7% by 5 years after reform and thereafter. In terms of high-tech industry own effects (as opposed to effects relative to low-tech industries), we find that broad offshoring intensities in high-tech industries increase by 59.5% about 5 years after reform and thereafter.

For intra-industry offshoring, we have similar results. Intra-industry offshoring intensities increase in high-tech industries relative to low-tech industries. The relative differential is 45.3% at 3 years after reform, increases gradually and reaches a differential of 124.3% by 5 years after reform and thereafter. With regard to own effects, we find that broad offshoring intensities increase in high-tech industries by 92.5% about 5 years after reform. All of the estimates reported above are statistically significant at conventional levels. In terms of magnitudes, these results are roughly in line with the difference-in-difference aforementioned estimators.

To sum up, following IPR reform, we find strong evidence for increased intra-industry offshoring in high-tech industries and also some evidence for increased broad offshoring in these industries. In both the differences-in-differences specifications and the event study analysis, the intra-industry offshoring estimates are much larger and more robust than broad offshoring estimates. We should note that the event-study estimates provide stronger evidence for increased broad offshoring vis-à-vis the differences-in-differences estimates.

Our paper differs from the empirical IPR-trade literature on a number of accounts. First, we construct a unique intermediate-goods-based

[3] See Feenstra (1998) and Campa and Goldberg (1997) for an overview of offshoring by advanced countries. See Hummels et al. (2001) for an empirical investigation of vertical specialization in world trade. See Tang (2006) for an empirical analysis of how declining communication costs affect trade in differentiated goods. See Baier and Bergstrand (2001) for an empirical analysis of rising trade levels and their causes. Most of the literature identifies reductions in tariffs, transportation and communication costs as the main driving forces behind the expansion in trade and offshoring. The notable exception is Baier and Bergstrand (2001) who find that two-thirds of the growth in world trade can be explained by income growth.

[4] See also Javorcik (2004), Bilir (forthcoming) and Ivus (2010).

[5] The importance of narrow offshoring is well documented in the literature. A recent study by Agnese and Ricart (2009), which considers offshoring aggregated over all trading partners, finds that narrow offshoring by the US accounts for around one third of broad offshoring. In addition, offshoring activities in general play a key role in global trade. According to World Investment Report, 2013, 60% of global trade consists of trade in intermediate goods and services (p.122).

measure of offshoring for each US industry disaggregated at the source country level. This differs from the existing literature noted above, which has used final goods trade, MNF related sales and payment levels.

Second, our offshoring measure captures MNF activity, albeit at the industry level, that takes place both within and outside the boundaries of the firm. This differs from Branstetter et al. (2006, 2011) and Bilir (forthcoming) who focus on intra-firm MNF activity measures and also from Javorcik (2004) who uses a binary Foreign Direct Investment (FDI) measure which equals one if a firm has invested in a country and zero otherwise.

Third, we are able to distinguish between offshoring types in each industry as broad offshoring and intra-industry offshoring. Our utilization of a rich information set (input–output (IO) tables coupled with bilateral import data) enables us to construct these measures in a straightforward way. The existing literature does not have this type of distinction, neither at the firm nor at the industry level. We should note that our empirical findings are qualitatively in line with the literature, especially the recent ones, which find that IPR reform increases trade or MNF activities.[6]

Our paper is also related to a large body of theoretical literature that investigates the impact of increased Southern IPR protection on MNF activity, Northern innovation and Southern imitation. This literature can be classified into two categories: quality-ladders models where innovation (R&D) aims at improving the quality of existing products, and variety expansion models where innovation aims at developing new varieties of goods. The variety-expansion models find that IPR reform increases the rate of FDI [see, among others, Helpman (1993), Lai (1998), Branstetter and Saggi (2011) and Gustafsson and Segerstrom (2011)]. The quality-ladders models, on the other hand, offer mixed results. For example Glass and Saggi (2002) find that IPR reform decreases the rate of FDI, whereas Dinopoulos and Segerstrom (2010) have the opposite result.[7] However, none of these papers explicitly considers fragmentation of production but instead assume full shifting of production to the South upon FDI success.

In the quality ladders literature, two papers indeed stand out as highly relevant to our empirical framework. The first is Şener (2006) who extends the North–South quality-ladders model by incorporating fragmentation of production between the North and the South within each industry. In Şener's setting, MNFs offshore an endogenously chosen portion of their production to the South. Similar to Glass and Saggi (2002), Şener (2006) finds that stronger IPRs lower the rate of FDI. However, different results emerge with regard to the offshoring indicators. Southern IPR reform increases both the fraction of multinational industries and the portion of offshored production within each industry. This finding is also in line with Glass (2004), another relevant paper in the quality-ladders literature. In this paper, Glass constructs a North–South quality ladders model with exogenous offshoring and imitation rates. She finds that a more stringent IPR regime in the South raises the fraction of offshoring industries.[8] In short, our empirical result that IPR reform leads to more intra-industry offshoring in patensensitive industries is in accord with the predictions of most of the recent theoretical work that uses a North–South growth and technology transfer framework.

The rest of the paper is organized as follows. Section 2 describes how the IPR reform dummy is constructed and explains how IPR reforms relate to technology transfer and offshoring. Section 3 describes the construction of our offshoring intensity measure and demonstrates some stylized changes in this measure by comparing the pre-reform and post-reform years. Section 4 presents our empirical specification, the data set, and the regression results. Section 5 discusses the issue of endogeneity regarding the timing of patent reforms. Section 6 concludes. Technical details of the construction of our offshoring measure, robustness checks, and variants of our empirical analysis are relegated to an online Appendix.

2. IPR Reform, technology transfer and offshoring

We follow Branstetter et al. (2006) in identifying the countries that undertook patent reform. Their main criterion is whether or not there was an expansion or strengthening of patent rights along five dimensions: "1) an expansion in the range of goods eligible for patent protection, 2) an expansion in the effective scope of patent protection, 3) an increase in the length of patent protection, 4) an improvement in the enforcement of patent rights, and 5) an improvement in the administration of the patent system." Branstetter et al. (2006) identify a total of 16 reforming countries and note that 15 of them expanded their patent rights protection along at least four of the five dimensions listed above. Table 1 provides the list of the reforming countries and the year of reform.[9]

How exactly does IPR reform affect manufacturing offshoring by US firms? One of the main concerns of globally-operating firms is the leakage of their proprietary technology via imitation, which can occur through labor turnover, contacts with local producers, or reverse engineering by local firms. With stronger IPRs in place, US firms can more effectively protect their technology against imitators and thus will feel more inclined to engage in technology transfer abroad. More specifically, firms who own both local and foreign production facilities will feel more secure in sharing their technology with their foreign affiliates and thereby increase their acquisition of intermediate goods from them. Similarly, firms who work with subcontractors abroad will feel more confident about sharing their technology and thus put in more orders of intermediate goods from them. In addition, local suppliers can respond to IPR reform by upgrading their technology to render a wider range of intermediate goods appealing to US firms.[10] In short, IPR reforms reduce the threat of imitation, raise the returns from technology transfer and thus are likely to lead to more offshoring either within the boundaries of the firm or outside the boundaries of the firm.[11]

In our econometric approach we follow Branstetter et al. (2006, 2011) and incorporate the broad measure of IPR reform as a binary

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[6] Branstetter et al. (2006, 2011) find that following IPR reform, MNFs expand the scale of their overseas activities. Ivus (2010) finds that strengthening IPRs in developing countries increases the value of exports by developed countries in patent sensitive sectors. Javorcik (2004) finds that weak IPR protection discourages foreign investment in technology-intensive sectors. Bilir (forthcoming) differentiates between industries based on their product lifecycle length. She finds that industries with shorter product life are insensitive to patent law changes, whereas industries with relatively longer product lifecycle length respond to improvement in patent laws by increasing their multinational firm activity. See also Smith (1999), Maskus and Penubarti (1995) and Co (2004).

[7] A full comparative discussion of this literature is beyond the scope of our paper. We refer the reader to Glass and Wu (2007) and also Dinopoulos and Segerstrom (2010) for a detailed comparison of quality-ladders vis-à-vis variety expansion models in the context of global IPR reform.

[8] Another closely related paper is by Şener and Zhao (2009) who differentiate between R&D races as local-sourcing- and foreign-sourcing-targeted R&D races. In the former type race, innovation success results in Northern production. In the latter, innovation success implies immediate outsourcing to the South (albeit a complete shifting of production to the South), a phenomenon which the authors label as the iPod cycle. Şener and Zhao find that strengthening Southern IPR leads to an increase in the frequency of iPod cycles and a larger fraction of industries engaged in outsourcing.

[9] See Branstetter et al. (2006, pp. 331–334) for a broad discussion on identifying IPR reforms. See the Appendix to their paper for a country-by-country analysis with further institutional details on the timing and strength of reforms. Branstetter et al. (2006, pp. 342–347) also make a case for exogeneity of IPR reforms by using empirical techniques and historical accounts, an issue which we take up in more detail in Section 5.

[10] One adverse effect could be that with more strict enforcement of patents, local suppliers may become more constrained in their use of technology and may become less competitive in producing intermediate goods for foreign markets.

[11] The increase in the returns to technology transfer as a first order response to IPR reforms is formally laid out in the models of Glass (2004) and Şener (2006). These models also consider the general equilibrium effects associated with changes in the North–South relative wage, Northern innovation and Southern imitation rates. In addition, survey-based evidence of Mansfield (1994) suggests that US executives will be more inclined to transfer more production and research to countries that strengthened their IPRs protection.

Table 1
Country — patent reform year.

Argentina	1996
Brazil	1997
Chile	1991
China	1993
Colombia	1994
Indonesia	1991
Japan	1987
Mexico	1991
Philippines	1997
Portugal	1992
S. Korea	1987
Spain	1986
Taiwan	1986
Thailand	1992
Turkey	1995
Venezuela	1994

Note: The country list and the year of patent reform follow from Branstetter et al. (2006) and (2011). IPR reform criteria is based on improvement along five dimensions: 1) range of goods eligible for patent protection; 2) effective scope of patent protection; 3) length of patent protection; 4) enforcement; 5) the administration of the patent system. See Section 2 first paragraph for details.

Table 2
Industries.

Industries
1. Food and kindred products
2. Tobacco products
3. Textile products
4. Apparel
5. Lumber and wood products
6. Furniture and fixtures
7. Paper and similar products
8. Industrial and other chemicals
9. Plastic and synthetic materials
10. Drugs, cleaning and toilette preparations
11. Rubber and miscellaneous plastics
12. Footwear, leather, and leather products
13. Non-metallic mineral manufacturing
14. Iron and steel manufacturing
15. Non-ferrous metals manufacturing
16. Metal containers
17. Machinery except electrical
18. Office machines and automatic data processing machines
19. Electric machinery, equipmentand supplies
20. Motor vehicles and related
21. Scientific and controlling instruments
22. Ophthalmologic and photographic instruments
23. Miscellaneous manufacturing

Note: For our empirical exercise we use a total of 23 manufacturing industries. This follows from our clustering of two-digit industries in a particular way to accommodate for the NIPAs 1999 comprehensive revision in industry codification beginning with 2000 for the input–output tables (See Appendix A for details). We then group these industries as high-tech and low-tech following Branstetter et al. (2011). Gray areas indicate high-tech industries, while the shaded gray area indicates an industry that is considered as high-tech in some robustness checks (See Section 2 for further details).

variable, which takes the value of zero before reform and one in the year of reform and thereafter. Even though this dummy variable embodies the common features of the IPR reform along the five dimensions listed above, it obviously misses the heterogeneity of reform across countries and along finer dimensions. For example, it is possible that patent length and patent coverage can vary across countries and across industries even within the same country. To study the responsiveness of offshoring along these finer dimensions, one can code up industry-specific patent laws across countries and conduct an empirical analysis. This is a fruitful avenue for further research but lies beyond the scope of the current paper.

Another point that is well established in the literature is that patent reforms may not have equal effects across industries. Basic intuition suggests that industries that rely more heavily on patents can give a larger response to IPR reform compared to industries that rely less heavily on patents. Mansfield (1995) argues that the strength of the IPR regime can be more important for industries such as drugs, cosmetic and healthcare products; chemicals; machinery and equipment; and electrical equipment. The same set of industries is also emphasized in Baldwin (1996). Most of the existing empirical IPR-trade papers incorporate this distinction between patent-sensitive and patent-insensitive industries in their empirical specification.[12]

In our empirical specification, we will capture this by following the industry classification of Branstetter et al. (2011, p.7), which is consistent with the classifications of other related studies, such as Maskus and Penubarti (1995) and Javorcik (2004), among others. To simplify labeling, we will henceforth refer to patent-sensitive industries as *high-tech* and patent insensitive industries as *low-tech* industries. Table 2 provides the complete breakdown of high-tech and low-tech industries.

Finally, it is also reasonable to expect that, in high-tech sectors, the response of intra-industry offshoring to IPR reform is larger than the response of broad offshoring to IPR reform. What could drive this? Intellectual property of a typical high-tech industry is more likely to be embedded in its intra-industry intermediates. Hence, once IPR reform takes place, firms in the high-tech industry are more likely to pursue offshoring of those intra-industry intermediates relative to offshoring of intermediates from the broad set of industries.

To see this, consider an auto maker operating in industry 20 (high-tech), producing some of its engine parts in-house domestically and importing some of them from its affiliate in China. Assume also that the automaker purchases GPS devices from industry 21 (high-tech) and steel from industry 6 (low-tech) both from domestic producers and third party producers in China. We conjecture that our auto maker, and for that matter a typical producer, would be relatively more familiar with the production technologies and also business strategies related to its own-industry intermediates (i.e., the engine in our example) compared to those related to the intermediates coming from other industries (i.e., GPS and steel in our example). Therefore, when China reforms its IPR policy, the automaker is more likely to pursue offshoring opportunities in its engine parts to China (either through its affiliate or a Chinese producer) in comparison to offshoring of the intermediate products from the other industries combined. Moreover, the response of broad offshoring measure to IPR reform is expected to be relatively diluted since broad offshoring contains low-tech industries that are less-sensitive to patent reform. To investigate whether intra-industry and broad offshoring intensities in high-tech industries respond to IPR reform differently, we construct both of these measures and use them in our regressions as the dependent variable.

3. Offshoring measure

A key aspect of our empirical approach is the construction of a unique measure of offshoring. We follow the spirit of Feenstra and Hanson who in several papers (1996 and 1999, among others) define foreign outsourcing (what we call offshoring) as the import of intermediate inputs.[13] In particular, our *broad offshoring* indicator measures at

[12] See among others, Branstetter et al. (2011, 2006), Javorcik (2004), Ivus (2010), Maskus and Penubarti (1995) and Smith (1999).

[13] More specifically, they compute the ratio of imported intermediate inputs to total expenditure on non-energy intermediates and call it a broad measure of foreign outsourcing share.

each point in time the dollar value of intermediate goods that a US industry imports from a particular country to produce one dollar worth of output. More specifically, our variable is a measure of "offshoring intensity" that evolves over time for each US industry-country pair. To construct this measure, we combine input–output (IO) tables with bilateral imports for the US. Data on IO coefficients are obtained from the US Bureau of Economic Analysis (BEA). Data on bilateral imports are from the Center for International Data at UC Davis, which were assembled by Robert Feenstra. See Appendix A for a detailed explanation of the construction of the offshoring variable.[14]

For each industry and year, we obtain from the IO tables the dollar value of inputs that US industry i gets from industry j to produce one dollar worth of i product at time t, (a_{ijt}). From the same source, we obtain the total consumption levels of the US economy in industry j, (C_{jt}). Total imports of the US economy from country c in industry j at time t, (M_{cjt}) come from the bilateral imports data set. With all this information, we are able to construct our broad offshoring intensity measure:

$$O_{cit} = \sum_{j} a_{ijt} \cdot \frac{M_{cjt}}{C_{jt}} \qquad (1)$$

which gives the offshored dollar value of inputs that industry i gets from all industries of country c to produce one dollar worth of industry i product at time t. Thus, as already mentioned, we are using a slightly extended version of the import proportionality assumption proposed by Feenstra and Hanson (1996, 1999) and used also in the construction of the OECD STAN data set, among others. In this extended version we assume that an industry i uses the input of industry j from country c in the same proportion as the economy-wide use of that particular input.[15] That is, if the motor vehicle industry uses \$0.15 worth of steel as an input to produce \$1 worth of output ($a_{ijt} = 0.15$), and 20% of all steel consumed in the US is imported from Brazil $\left(\frac{M_{cjt}}{C_{jt}} = 0.2\right)$, then we estimate that to produce \$1 worth of output in motor vehicle industry, 3 cents worth of Brazilian steel is used ($0.15 \times 0.2 = \$0.03$).

Moreover, we have to make some additional structural assumptions to accommodate the change in industry classification for the 2000–2006 years, following the NIPAs revision in industry codification.[16] Beginning with 2000, the BEA has started clustering certain sets of industries, which resulted in the IO tables containing fewer manufacturing sectors than in previous years. Thus, in order to retrieve the larger set of industries for the 2000–2006 period we combine the consumption data and the IO coefficients in the clustered industries with the consumption and IO coefficients in 1999. More specifically, we construct the new consumption and IO coefficients for 2000–2006 using a particular weighting based on the 1999 data and assuming this to be constant for 2000 and onwards (see Appendix A for a detailed explanation).

Finally, we construct a measure of *intra-industry* offshoring O_{cit}^{INT} to capture offshoring that takes place within the same industry. Our main motivation comes from Feenstra and Hanson (1999, p. 924), who argue that a narrowed-down measure such as this can better capture "the transfer overseas of production activities that could have been done by that company in the US". To give an example, they note that the import of steel by a US auto producer is not normally considered as offshoring but that the imports of auto parts by the US auto producer are usually considered as offshoring. In more general terms, a narrow measure that focuses on intra-industry transactions can better proxy for the extent of within-MNF activity and arm's length subcontracting activity, two types of activities that are closely associated with offshoring, as opposed to direct purchases of intermediate goods outside the boundaries of the firm that do not involve an immersed contractual relationship and/or technological exchange. The intra-industry offshoring measure, along with the broad offshoring measure, has been widely used in the literature since the influential work of Feenstra and Hanson.[17] Another motivation is to examine the possible differential response to IPR reform of intra-industry offshoring in high-tech sectors vis-a-vis broad offshoring in high-tech sectors, as discussed in Section 2.

To obtain our intra-industry offshoring intensity measure we set $j = i$ in Eq. (1),

$$O_{cit}^{INT} = a_{iit} \frac{M_{cit}}{C_{it}} \qquad (2)$$

which gives the offshored dollar value of inputs that industry i gets from the same exact industry of country c to produce one dollar worth of industry i product at time t.[18]

3.1. Offshoring before and after reform: a first look

To provide a general picture of the trends in offshoring, we show the unconditional average offshoring intensity levels (measured in cents per dollar of output) before and after IPR reforms in Figs. 1–4. The bars in these figures represent the sample averages based on our industry-country pair data.[19] Panel A in Fig. 1 shows the substantial increase in average broad offshoring intensity after IPR reform, from 0.07 cents for each dollar of output, to close to 0.20 cents for each dollar. Panel B in Fig. 1 shows that on average, low-tech industries have more than doubled their broad offshoring intensity, whereas high-tech industries have more than tripled their corresponding measure. Moreover, Panel B illustrates that high-tech industries tend to offshore more than low-tech industries, both before and after IPR reform. We should note that our data is at the industry-country pair level and thus the offshoring intensities can increase substantially once we calculate a typical US industry's offshoring to *all* 16 countries in the sample. For example, at

[14] Data can be downloaded from http://cid.econ.ucdavis.edu/.

[15] Since there are no country-specific IO tables for the US, to calculate industry-country pair measures of offshoring, we extend the import proportionality assumption by multiplying a_{ijt} in Eq. (4) by M_{cjt}, imports from country c by industry j. This differs from Feenstra and Hanson (1996, 1999) who instead multiply M_{jt}, imports by industry j aggregated across all trading partners. We use M_{cjt} because our goal is to construct a measure of offshoring intensity mapped against the US trading partners, whereas Feenstra and Hanson use M_{jt} because they seek to construct a measure of offshoring intensity at the industry level with no particular interest in the countries from which imports originate. Falk and Wolfmayr (2005) use the same approach to construct an offshoring measure by country of origin for seven EU countries. Even though the import proportionality assumption is widely used in the literature [see Hummels et al. (2001), Amiti and Wei (2005, 2009) and Grossman and Rossi-Hansberg (2006)], we must note that it provides only a proxy measure of offshoring intensity, but constitutes our "best guess" in the words of Amiti and Wei (2009) given the aforementioned lack of IO tables for the US broken down by imported and domestic inputs. In a recent paper, Winkler and Milberg (2009) question the proportionality assumption and discuss the implications using data from Germany, which provides direct measures of imported and domestic inputs at the industry level. And as they point out, the results might be either upward biased or downwards, "[…] depending on the cross-sectoral variation in domestic input" (pp.12–13).

[16] NIPAs revision was designed by the BEA to increase consistency between IO tables, GDP industry tables and NIPA tables.

[17] See among others Hijzen et al. (2005), Egger and Egger (2003, 2006), Geishecker (2006) and Geishecker and Holger (2008).

[18] In Appendix I, we also consider the IPR response of two additional measures of offshoring intensity, high-tech intensive offshoring and low-tech intensive offshoring, which capture offshoring from industry i to high-tech industries and low-tech industries, respectively.

[19] In order to compute the average in the descriptive statistics, each country, industry and year is given the same weight, that is, each observation is considered as one data point. Thus, these unweighted averages cannot be interpreted as the behavior of the average US industry to an average offshoring country.

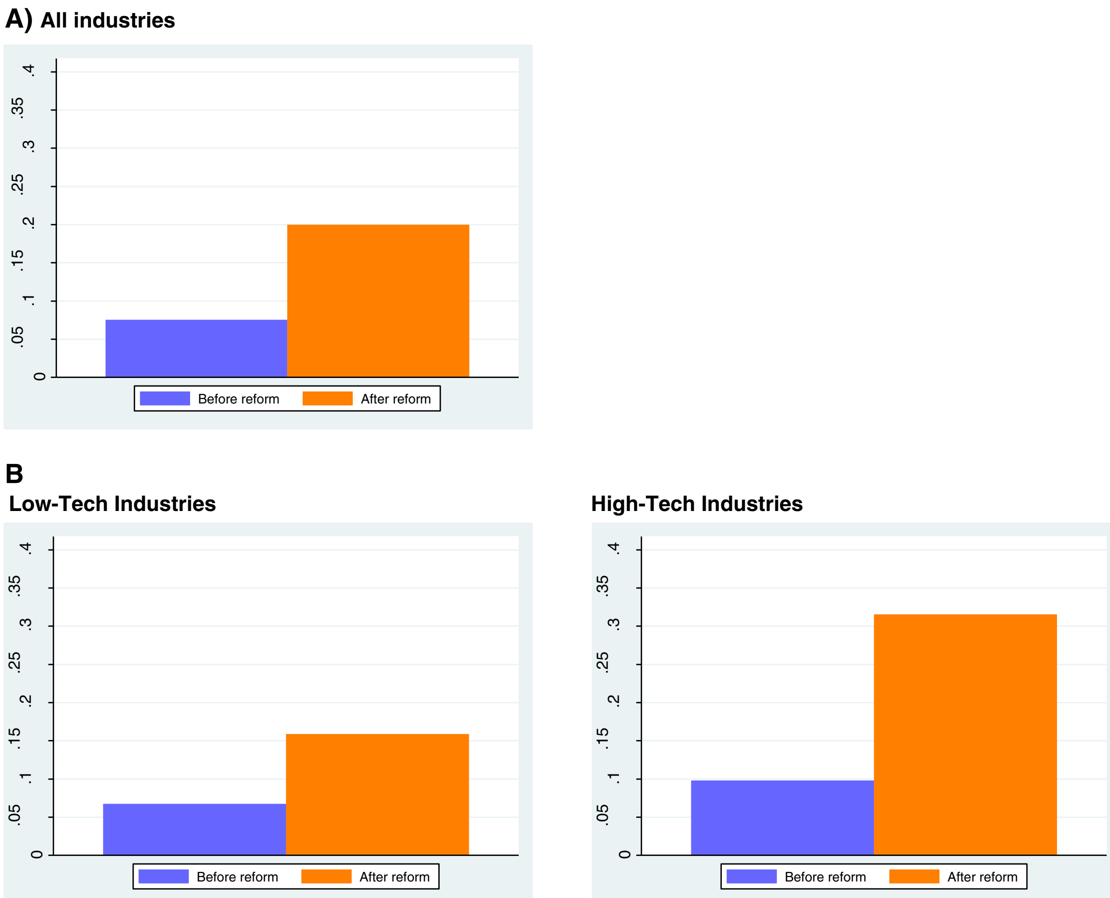

Fig. 1. Broad offshoring intensity (cents per dollar of output).
Note: We define broad offshoring intensity for an industry-country pair as the value of intermediate goods that a US industry imports from all industries of a given country to produce one dollar worth of output. The bars in Fig. 1 show separately the unconditional averages for broad offshoring intensities over the before-reform years and after-reform years. In Panel A, the averages are based on all of the industry-country pairs in our sample. In panel B, we report the averages separately for the industry-country pairs that belong to the high-tech (patent-sensitive) industry group and for the pairs that belong to the low-tech (patent-insensitive) industry group. The IPR reform years for our sample of countries are given in Table 1. The list of high-tech and low-tech industries is in Table 2.

the industry-level the average post-reform broad offshoring intensity to all countries in the sample is 3.2 cents (0.2 cents $\times$ 16) per dollar.[20]

Similarly, Fig. 2 demonstrates the substantial increases in average intra-industry offshoring intensity measures. A quick glance at Fig. 2 suggests that the percentage increases in intra-industry offshoring measures are in similar magnitude to the changes in broad offshoring measures. As expected, the levels for broad offshoring intensity are larger, since they contain the intra-industry offshoring intensity in them. By comparing Figs. 1 and 2, which are drawn with the same scale, one can see that intra-industry offshoring is a sizeable component, accounting for roughly half of broad offshoring at the industry level.

Figs. 3 and 4 show the broad and intra-industry offshoring intensities at the individual industry-level. For broad offshoring intensity, the three industries that register the largest changes are “8. Industrial and other chemicals”, “18. Office machines and automatic data processing”, and “9. Plastic and Synthetic materials”. Notice that the first two are in the high-tech industry group, whereas the last one is in the low-tech industry group. When looking at how intra-industry offshoring intensity changes after IPR reform, we observe a consistent increase throughout all high-tech industries. That is not the case for low-tech industries. While offshoring intensity largely increases for some of these industries after reform, some industries indeed experience a decline in their intra-industry offshoring intensity.

4. Empirics

4.1. Econometric specification

To assess the impact of IPR reform on offshoring, we employ a difference-in-difference approach, following Branstetter et al. (2006, 2011). Our empirical analysis differs from Branstetter et al. in three key aspects. First, as our dependent variables, we consider offshoring measures at the industry level, unlike Branstetter et al. who consider mostly parent-affiliate measures at the firm level.[21] Even though our measure is at a less disaggregated level, it has the advantage of capturing a wider spectrum of MNF and Northern firm activity. This is because it includes both parent-affiliate activities that take place within the boundaries of the firm and also arm's length activities such as subcontracting to outside foreign firms. Second, we have information about each

[20] Our sample of 16 countries account for 26.6% percent of the world output in year 1990 (the midpoint of our data coverage); thus, offshoring values can increase even more once all other trading partners are included.

[21] We should note that Branstetter et al. papers use other dependent variables as well. More specifically, Branstetter et al. (2011) use Southern industry-level data to assess whether IPR reform has a net positive effect on aggregate production per industry. In addition, Branstetter et al. (2006) consider host-country patent data differentiated as resident and non-resident patent filings to estimate the impact of IPR reform on patenting activity.

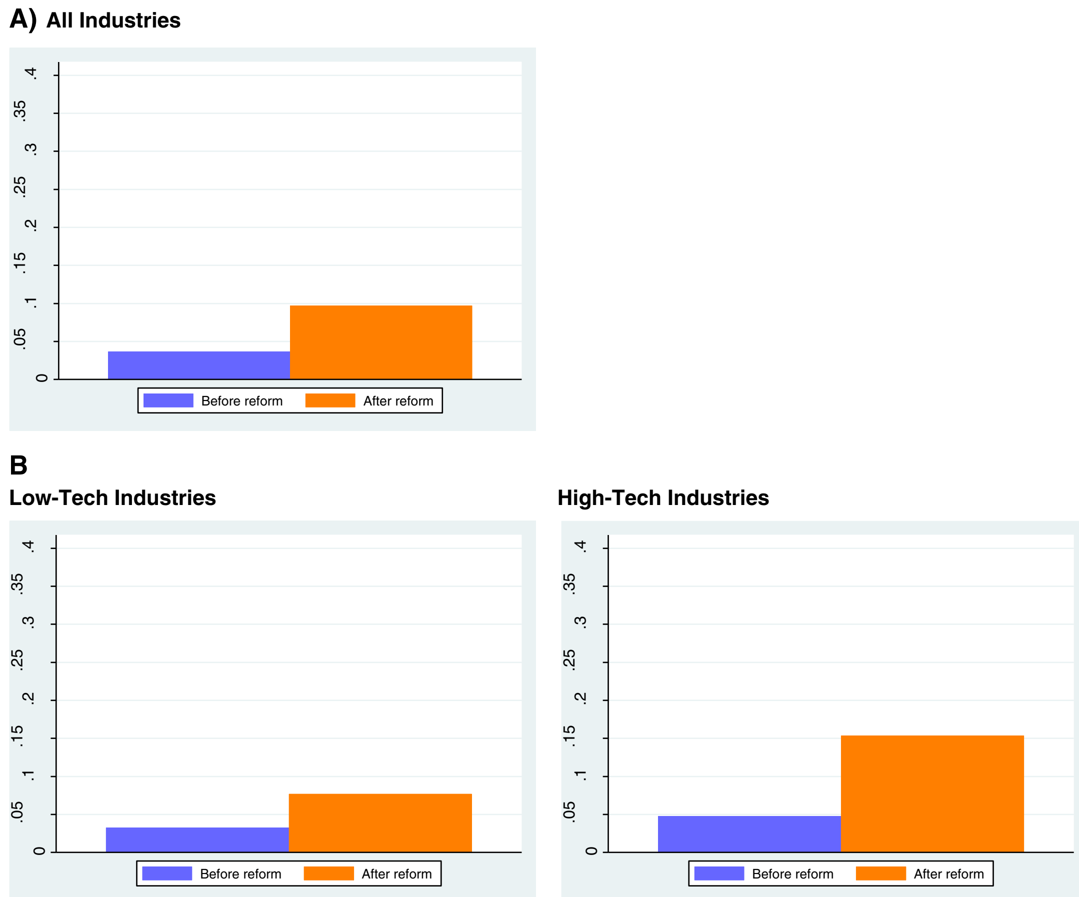

Fig. 2. Intra-industry offshoring intensity (cents per dollar of output).
Note: We define intra-industry offshoring intensity (also known as narrow offshoring) for an industry-country pair as the value of intermediate goods that a US industry imports from the same exact industry of a given country to produce one dollar worth of output. The bars in Fig. 2 show separately the unconditional averages for intra-industry offshoring intensities over the before-reform years and after-reform years. In Panel A, the averages are based on all of the industry-country pairs in our sample. In panel B, we report the averages separately for the industry-country pairs that belong to the high-tech (patent-sensitive) industry group and for the pairs that belong to the low-tech (patent-insensitive) industry group. The IPR reform years for our sample of countries are given in Table 1. The list of high-tech and low-tech industries is in Table 2.

industry's distribution of offshoring across *all* other industries. Thus, we are able to distinguish between broad offshoring and intra-industry offshoring. Third, we use time series data from 1973 up to 2006 and thus extend the time period of Branstetter et al. (2011), which starts in 1982 and ends in 1999.

Methodologically, we track the evolution of offshoring activities performed by each US industry across countries and industries, and over time. We create a dummy variable to capture IPR reform and estimate how offshoring changes in response to reform, controlling for fixed effects and country characteristics. We also extend the analysis by classifying industries as high-tech and low-tech in order to assess the possible differential response by industry type. With multiple time periods and groups (countries in our case) our difference in difference specification at the industry-country level is:

$$O_{cit} = \alpha_{ci} + \alpha_t + \beta_c t + \beta_1 H_{ct} + \beta_2 R_{ct} + \beta_3 R_{ct} \cdot Tech_i + \varepsilon_{cit} \quad (3)$$

where the subindex c identifies the country to which the US industry is offshoring, i is the industry index, and t is the year index. As already discussed, our measure of offshoring O_{cit} represents the value of imported intermediate inputs that the US industry i purchases from country c in order to produce one dollar worth of value in year t.

In estimating Eq. (3) we regress O_{cit} on country-industry pair fixed effects α_{ci}, time fixed effects α_t, and country-specific linear time trends $\beta_c t$, and a number of time-varying country characteristics H_{ct}, which include GDP per capita, GDP, real exchange rate with respect to the US dollar and a measure of trade openness (total trade over GDP). Following Branstetter et al. (2006, 2011), we use a Reform Dummy variable (R_{ct}) that takes the value of one in the year of IPR reform and thereafter for country c, and zero otherwise.[22] Its coefficient shows the average change in broad offshoring intensity in all industries after a strengthening of the IPR regime in country c. Hence, $\beta_2 > 0$ implies an in US offshoring intensity increases to the reforming country.

[22] Using the IPR reform dummy of Branstetter et al. in the context of a difference-in-difference approach has a number of advantages over the cross-country regressions that rely on IPR indices such as Ginarte and Park (1997). First, by using a difference-in-difference approach in a disaggregated panel data set, one can exploit the time series variation in the data while controlling for many factors (such as country-industry fixed effects, time fixed effects, country specific trends, and time-variant country characteristics and etc.) that affect the dependent variable in question. Second, the IPR reform dummy of Branstetter et al. (2006) is a broad measure that combines information from Maskus (2000) and Qian (2007), who provide lists of reforming countries, with that from Ginarte and Park (1997), who provide a cross-country IPR protection index with 5-year intervals. Branstetter et al. (2006) further supplement this information by conducting extensive interviews with patent lawyers and multinational managers and reading of secondary sources. One disadvantage of the Reform dummy is that it is a binary measure and thus in a certain sense less refined compared to the Ginarte and Park index which varies between 0 and 5. Nonetheless, we do run some robustness checks using the most updated version of Ginarte and Park's index provided in Park (2008) (available at: http://www.american.edu/cas/economics/pdf/upload/indexofpatentprotection1960–2005r.pdf) by assuming that the index gradually evolves between the two reported 5-year intervals. The qualitative results follow the same pattern as those obtained with the IPR reform dummy of Branstetter et al. (2006), and the quantitative effects are also in similar magnitude. We provide the regression results in Appendix G.

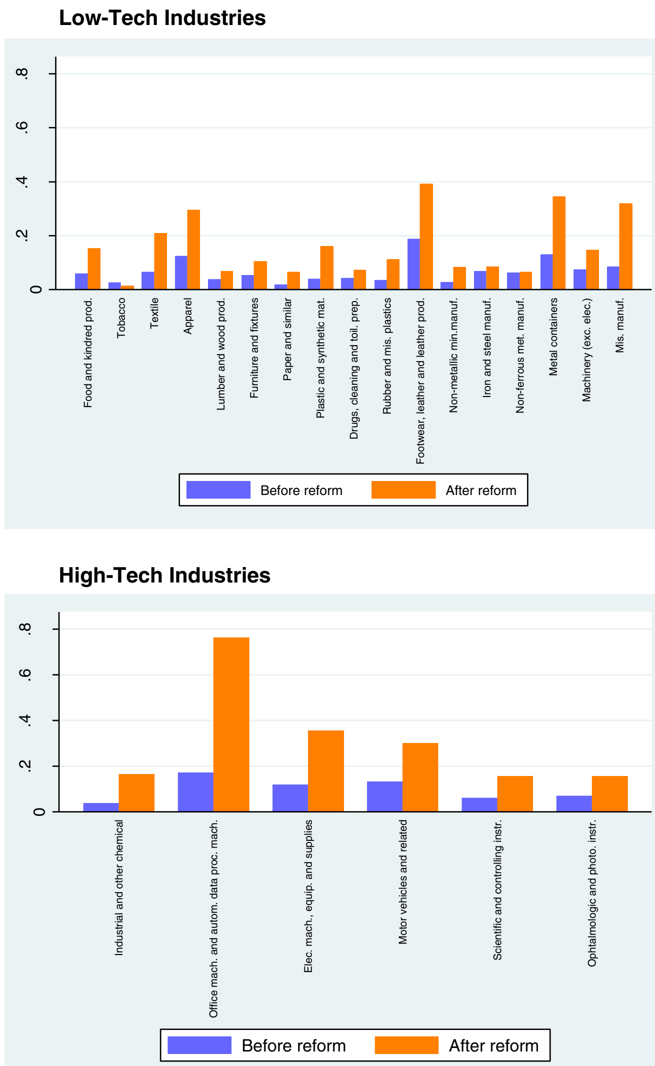

Fig. 3. Broad offshoring intensity (cents per dollar of output).
Note: We define broad offshoring intensity for an industry-country pair as the value of intermediate goods that a US industry imports from all industries of a given country to produce one dollar worth of output. The bars in Fig. 3 show separately the unconditional averages for broad offshoring intensities at the industry level over the before-reform years and after-reform years. The top panel shows these averages for each high-tech (patent-sensitive) industry. The bottom panel shows the averages for each low-tech (patent-insensitive) industry. The IPR reform years for our sample of countries are given in Table 1. The list of high-tech and low-tech industries is in Table 2.

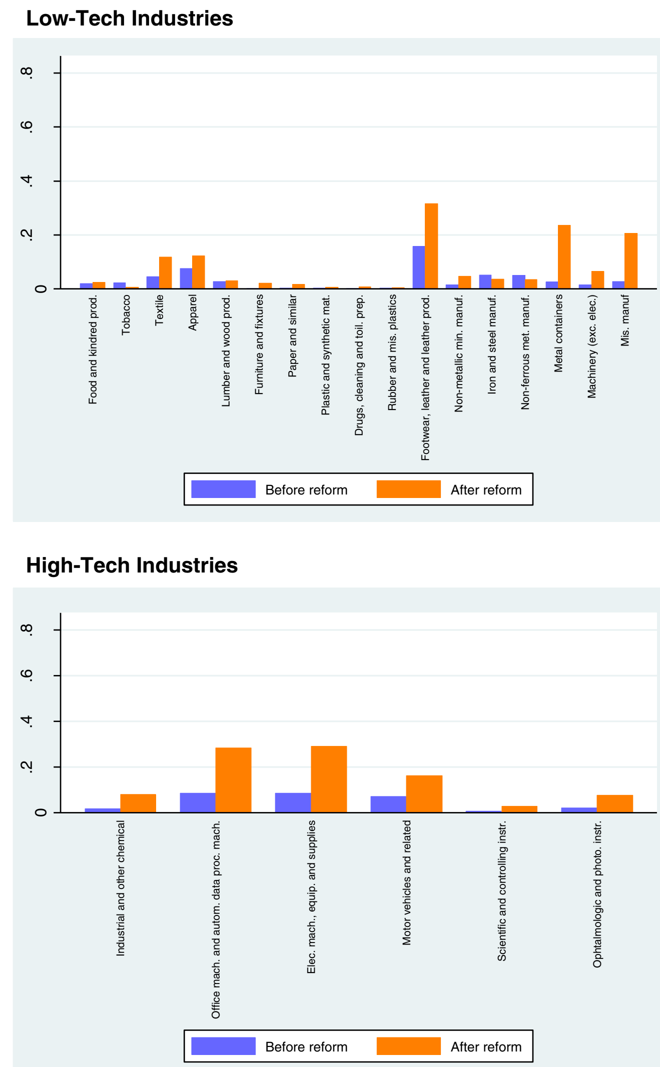

Fig. 4. Intra-industry offshoring intensity (cents per dollar of output).
Note: We define intra-industry offshoring intensity (also known as narrow offshoring) for an industry-country pair as the value of intermediate goods that a US industry imports from the same exact industry of a given country to produce one dollar worth of output. The bars in Fig. 4 show separately the unconditional averages for intra-industry offshoring intensities at the industry level over the before-reform years and after-reform years. The top panel shows these averages for each high-tech (patent-sensitive) industry. The bottom panel shows the averages for each low-tech (patent-insensitive) industry. The IPR reform years for our sample of countries are given in Table 1. The list of high-tech and low-tech industries is in Table 2.

Similarly, we use a binary variable $Tech_i$ to distinguish between high-tech and low-tech industries. Following the literature, we seek to test the hypothesis that high-tech industries, as heavy users of intellectual property, would respond more strongly to IPR reform than low-tech industries. Particularly, $Tech_i$ equals one for the high-tech industries listed in Table 2. We then interact $Tech_i$ with the Reform Dummy variable R_{ct}. The coefficient β_3 on the interaction variable ($R_{ct} \cdot Tech_i$) captures the differential impact of IPR reform on offshoring in high-tech industries. Thus, $\beta_3 > 0$ implies that patent reform exerts an additional positive impact on US offshoring intensity in high-tech industries.

We also run additional regressions using the same specification in Eq. (3) but this time with O_{cit}^{INT}, intra-industry offshoring intensity, as our dependent variable:

$$O_{cit}^{INT} = \alpha_{ci} + \alpha_t + \beta_c t + \beta_1 H_{ct} + \beta_2 R_{ct} + \beta_3 R_{ct} \cdot Tech_i + \varepsilon_{cit}. \quad (4)$$

The interpretations of the estimated coefficients remain the same as above.

4.2. Data set

We use several sources to construct our final data set and end up with a total of 23 US manufacturing industries, 6 high-tech and 17 low-tech (see Table 2) over the period 1973–2006 to 16 different countries (see Table 1). Each country in the sample has experienced a patent reform episode at one point during this time period. As aforementioned, to construct the offshoring intensity variable we combine IO tables (from the BEA) and bilateral imports data (from the Center for International Data at UC Davis). The IO tables are unavailable for certain years; thus, our data covers 23 years out of the 34 years.[23] The Reform Dummy and the High-Tech Dummy variable for industries are borrowed from Branstetter et al. (2006, 2011).

Other independent variables include: GDP, GDP per capita, trade openness (exports plus imports over GDP), Real Exchange Rate (RER)

[23] Final years are restricted to the availability of IO tables: 1973, 1974, 1975, 1976, 1978, 1979, 1980, 1981, 1983, 1984, 1985, 1986, 1996, 1997, 1998, 1999, 2000, 2001, 2002, 2003, 2004, 2005 and 2006.

with respect to the US dollar, all of which follow from Branstetter et al. (2006, 2011). We include both GDP per capita and GDP in the spirit of the standard gravity equation where both variables are included to capture the mass associated with each country and its impact on trade flows [See, e.g. Rose (2005), Frankel and Rose (2002)]. The US is expected to do more offshoring to larger and richer economies, holding all else constant. We include trade openness to account for the country's broad degree of integration with the world economy. The US is expected to do more offshoring to countries that are relatively more integrated with the rest of the world. We include RER, which is defined as foreign currency per US dollar adjusted for relative price ratios. Higher values of RER imply an appreciated dollar relative to the local currency, increasing the likelihood of offshoring by US industries. Hence, we expect a positive sign for the RER coefficient. GDP, GDP per capita, trade openness are obtained directly from the World Development Indicators (2009).[24] RER is constructed by using the nominal exchange rates from the Penn World Tables 6.3 and inflation rates from WDI (2009) for most of the countries.[25] However, for China, inflation is taken from the IMF's World Economic Outlook (WEO) from 1980 onwards and assumed to be equal to the average between 1980 and 1985 for the seventies. For Brazil, inflation for the seventies is taken from Fundación Getulio Vargas.[26]

Table 3 shows the descriptive statistics for the dependent and independent variables used in the regressions. In particular, it shows that in our industry-country pair sample, the average broad offshoring intensity is 0.13 cents per dollar produced, with a maximum of 5.7 cents and a minimum of almost zero cents per dollar, while the average intra-industry offshoring intensity is 0.07 cents per dollar, half of our broad offshoring measure, with a maximum of 5.38 cents. The rest of the figures show the heterogeneity in the country sample, in terms of development, size and openness. The sample includes a number of low GDP per-capita countries such as Indonesia and China in the 1970s, and advanced economies such as Japan and Spain. Particularly, the minimum GDP per capita of 136 US dollars is for Indonesia in 1973, while the maximum of close to 37,000 US dollars is for Japan in 1996. The differences between the countries are also evident regarding size as measured by GDP. In 2006, Philippines and Colombia are the smallest economies in the sample, and their GDP levels do not reach 4% of Japan's GDP that same year, the largest economy by far. The sample also includes a number of countries that differ substantially in terms of their openness levels. Moreover, the sample period coincides with of the dramatic changes realized by China, Mexico and Turkey. All of them were relatively closed in the 1970s – with a trade openness value below 20% of GDP – and became very open economies in the 2000s — with values above 50%.

4.3. Regression results

We now present our estimates of Eqs. (3) and (4) for the time period 1973–2006, using our entire industry-country pair sample. For each equation, we first run a regression only with the Reform Dummy (R_{ct}) and then we add the interaction term ($R_{ct} \cdot Tech_i$). We conjecture that offshoring intensity changes in a proportional way in response to IPR reform. We thus take the log of our dependent variables, broad offshoring and intra-industry offshoring intensities, in order to have a precise semi-elasticity interpretation for the estimated coefficients on Reform. In all regressions, we report robust standard errors clustered on country.[27]

Table 4 presents our regression results with *broad offshoring* intensity, O_{cit}, as the dependent variable. We consider a number of alternative specifications to check the robustness of our findings. Columns (1) and (2) show our parsimonious regressions with year fixed effects, industry-country pair dummies and country-specific linear trends but without country control variables. Columns (3) and (4) present our baseline regressions, which add country controls. Column (5) considers an alternative High-Tech Dummy, which is constructed by adding industry 10 (Drugs, Cleaning and Toilette Preparations) to the high-tech group since pharmaceuticals are in this category. Columns (6) and (7) present the regressions by including industry-specific time trends.

We first note in Table 4 that the R-squared values in our parsimonious regression pair in Columns (1) and (2) are reasonably high and quite close the R-squared values in the baseline regression pair in Columns (3) and (4). Thus, the addition of country controls does not appear to generate a substantial gain in R-squared levels once fixed effects are accounted for. In Columns (1), (3), and (6), the coefficient β_2 on the Reform Dummy R_{ct} is positive but not significant. Thus, following IPR reform, broad offshoring intensity on average does not change in a statistically significant way. In Columns (2), and (4), when the interaction term is added, the coefficient β_2 on the Reform Dummy R_{ct} still remains insignificant; however, the coefficient β_3 on the interaction term $R_{ct} \cdot Tech_i$ is around 0.273 and marginally significant at 10% level. Hence, high-tech industries increase their broad offshoring intensity by 31% (found by $e^{0.273} - 1$) relative to the insignificant 4% increase in low-tech industries (found by $e^{0.013} - 1$). Nonetheless, the marginal significance of the interaction term $R_{ct} \cdot Tech_i$ vanishes in Column (5) when we consider industry 10 as a high-tech industry and in Column (7) when we include industry-specific time trends. Thus, the increase in broad offshoring intensity by high-tech industries relative to low-tech industries, tough significant in our baseline specification, is not robust to considering alternative specifications.

Moreover, for the specifications in Columns (2), (4), (5) and (7) we also examine the changes in broad offshoring intensities in high-tech industries on their own, that is, in absolute terms as opposed to focusing on the change relative to low-tech industries. This simply involves testing the null hypothesis $\beta_2 + \beta_3 = 0$. We find that we cannot reject the null hypothesis at conventional level of significance (the exact p-values for the F-tests are reported at the lower part of Table 4).

Similarly, Table 5 presents our regression results with *intra-industry offshoring*, O_{cit}^{INT}, as the dependent variable.[28] We consider the same alternative specifications as in the case of broad offshoring intensity. We again first note that in Table 5 the R-squared values in our parsimonious regression pair in Columns (1) and (2) are reasonably high and quite close the R-squared values in the baseline regression pair in Columns (3) and (4). In Columns (1), (3), and (6), the coefficient β_2 on the Reform Dummy R_{ct} is positive but not significant. Thus, following IPR reform, intra-industry offshoring intensity on average does not change in a statistically significant way.

In Columns (2) and (4), when the interaction term is added, the coefficient β_2 on the Reform Dummy R_{ct} still remains insignificant; however, the coefficient β_3 on the interaction term $R_{ct} \cdot Tech_i$ is 0.824 and significant at 5% level. Contrary to what happens when broad offshoring is the dependent variable, we find that this coefficient remains significant and positive for all specifications thereafter, even though it gets smaller in some cases. In particular, in Column (5) when we consider industry 10 as a high tech industry, the significance of $R_{ct} \cdot Tech_i$ coefficient remains at 5%, and its magnitude goes down to 0.641. Similarly, in Column (5) when we include industry-specific time trends, the significance of $R_{ct} \cdot Tech_i$ coefficient remains at 5% with a magnitude of 0.467. To sum up, our baseline regression of Column (2) suggests that in high-

[24] For Taiwan, data on GDP, GDP per capita, trade and inflation come from National Sources.

[25] When computing RER we took 1973 as the base year and normalized RER to 100 for all countries in that year.

[26] See Marc-Andreas Muendler (2003) for further information on Brazilian inflation data.

[27] We used Stata version 12 to perform our empirical analysis. Our data set and software program are available at http://www1.union.edu/senerm. For all regressions in the main text, we used the xtreg command in Stata with robust and cluster by country options.

[28] We note that for certain industry-country pairs the level of intra-industry offshoring is zero. These values are thus excluded from our log-based regressions since the log of zero is undefined. Consequently, in the regressions shown in Table 5 there are 118 observations missing.

Table 3
Summary statistics for the main variables.

	Mean	St. dev.	Min.	Max.
Broad offshoring intensity (cents per US$)	0.13	0.35	4.60E-06	5.7
Intra-industry (narrow) offsh. int. (cents per US$)	0.07	0.23	0	5.38
GDP per capita (US$)	5069	6928	136	36861
GDP (billions US$)	377	782	7.23	4670
Real exchange rate	134.84	88.05	44.13	541.50
Trade openness (X + M)/GDP	0.5	0.27	0.08	1.56
Log broad offshoring intensity	−8.275	1.918	−16.891	−2.864
Log intra-industry (narrow) offsh. int.	−10.334	3.159	−21.971	−2.922
Log GDP per capita	7.837	1.204	4.911	10.515
Log GDP	25.624	1.365	22.701	29.172
Log real exchange rate	4.765	0.482	3.787	6.294
Log trade openness	−0.862	0.587	−2.513	0.444

Note: Broad offshoring intensity for an industry-country pair is defined as the value of intermediate goods that a US industry imports from all industries of a given country to produce one dollar worth of output. Similarly, intra-industry offshoring intensity measures offshoring (again understood as imported intermediate inputs) that takes place within the same industry. To compute the offshoring measures, we combine the input–output (IO) tables with bilateral import data for the US (see Appendix A for more details). For most countries, GDP and GDP per capita in US$ come from the World Bank World Development Indicators (WDI) and otherwise from national sources. Real Exchange Rate is calculated by using nominal exchanges rates and inflation measures, which are also from the WDI. Trade openness is computed as (Exports + Imports)/GDP and is available from the WDI.

tech industries, intra-industry offshoring intensity increases by 128% (found by $e^{0.824} - 1$) relative to the insignificant −21.1% (found by $e^{-0.238} - 1$) decrease in low-tech industries.[29] As the lower bound, our regression with industry-specific trends put these numbers at 59.5% (found by $e^{0.467} - 1$) and −13.4% (found by $e^{-0.144} - 1$), respectively.

We also test the hypothesis that $\beta_2 + \beta_3 = 0$ and found that it is rejected at significance levels close to 5% in specifications Columns (2) and (4), and at marginal significance level of 10% in Column (5). It cannot be rejected though in Column (7) at conventional levels of significance (the exact p-values for these F-tests are reported in Table 5 lower part).

To what extent is IPR reform responsible for increased offshoring? Our baseline regressions show that intra-industry offshoring intensity in high-tech industries increases by around 79.6% in absolute terms (follows from $e^{0.586} - 1$, where $0.586 = 0.823 - 0.238$ is found by adding up the coefficients for R and R · Tech in column (4)). As a lower bound, the intra-industry increase in absolute terms is 38.1% (follows from $e^{0.323} - 1$, where $0.586 = 0.323 - 0.144$ is found by adding up the coefficients for R and R · Tech in column (7)). The average intra-industry offshoring intensity levels in high-tech industries before and after reform are 0.047 and 0.153 cents per dollar of output, respectively. This implies a percentage increase of 222.1%. Thus IPR reform can indeed account for 35.8% or 17.1% of the increase in intra-industry offshoring by high-tech industries, based on the baseline or lower-bound results, respectively, to our sample of 16 countries.[30]

Finally, observe that in both Tables 4 and 5, the country control variables are not significant. The only exception is trade openness, which has the expected sign and is significant. The results suggest that a one standard deviation increase in trade openness (0.587) is associated with a 41.3% increase in broad-offshoring intensity (found by $e^{0.587 \cdot 0.590} - 1$), and a 22.2% increase in intra-offshoring intensity (found by $e^{0.587 \cdot 0.345} - 1$).

For both broad and intra-industry offshoring measures, we considered the baseline specifications (Columns (3) and (4) of Tables 4 and 5) and performed the following robustness checks one at a time. We excluded from the data set China and Argentina, two countries for which some concerns have been raised regarding the enforcement of new patent laws. We excluded trade openness as a covariate as it may respond to IPR reform and distort the interpretation of the IPR dummy. We excluded GDP as a covariate following the specification of Branstetter et al. (2011, p. 34). We considered separate country and industry fixed effects *instead* of country-industry pair fixed effects. We replicated the regressions in Tables 4 and 5 without taking the logs of the offshoring variables. We re-ran our regressions with complete coverage of the 1973–2006 time period by making certain assumptions regarding the input–output coefficients for the missing years. We found that the results did not change in any major way.[31]

5. Endogeneity of reform and timing of changes in offshoring

Our empirical specification treats IPR reforms as exogenous, at least with respect to offshoring intensity at the industry level. It is quite conceivable that there are omitted variables that correlate with both the timing of patent reform and our constructed offshoring indicator. For example, countries above a certain level of development and infrastructure could feel the pressure to build a better IPR protection system and at the same time attract more offshoring due to their better infrastructure. This type of endogeneity could lead to biased estimates in the regressions.

Even though we cannot completely rule out such endogeneity concerns, we can investigate their plausibility more carefully. For starters, we test whether or not there has been a clear upward trend in offshoring intensity prior to IPR reform, as a way to assess whether patent reform responds endogenously to changes in offshoring. To do this, we conduct an event-study analysis using the methodology of Jacobson et al. (1993). We normalize the year of IPR reform to zero and regress our offshoring measure on a set of dummies for pre- and post-reform years. As our baseline regression, we kept the pre- and post-reform intervals to 5 years. We construct the complete data set for the 1973–2006 period by making a number of assumptions about the input-out (IO) coefficients for the missing years.[32]

The results are presented in Table 6. As in the main analysis, the dependent variables are broad offshoring intensity O_{ict} and intra-industry offshoring intensity O_{ict}^{INT}. In this event study exercise, we use data for the entire time period; thus, the number of observations increases from 8464 to 12,512.[33] The dummy variables of interest are defined as follows. Pre5 equals one for 5 years before reform and all

[29] Since Reform is a binary variable that implies large discreet changes by construction, we calculate the percentage change in offshoring intensity by using $e^{\beta dX} - 1$, where dx is the change in reform and equals 1.

[30] The offshoring levels and the changes in levels may appear very small at first sight. However, we should again note that our unit of analysis is industry-country pair. If we focus on offshoring intensity by a typical industry to *all* countries in the sample, the numbers can look more substantial. For example, the average increase in intra-industry offshoring intensity by a high-tech industry that offshores to *all* 16 countries in our sample is $(0.04762) \cdot (e^{0.586} - 1) \cdot (16) = 0.607$ cents per dollar produced.

[31] Complete details on these robustness checks are provided in the Supplementary Appendix.

[32] In particular, we made the following assumptions for the IO coefficients: IO year 77 = IO year 76; IO year 82 = IO year 81; IO year 87, 88, 89, 90 = IO year 86; IO year 91, 92, 93, 94, 95 = IO year 96.

[33] For the intra-offshoring regressions this number is reduced to 12,360 since not all US industries offshore (at the narrow level) from all 16 countries in the sample.

Table 4
How IPR reforms affect broad offshoring.

Dependent variable	Log US broad offshoring intensity from industry *i* to country *c* at time *t*.						
Sample coverage	1973–2006 (with gaps), 16 countries, 23 US industries						
	(1) Country controls excluded	(2) Country controls excluded	(3) Country controls included	(4) Country controls included	(5) Industry 10 as high-tech	(6) Industry-specific time trends	(7) Industry-specific time trends
Reform dummy (R)	0.112	0.0409	0.0583	−0.0129	0.0135	0.0583	0.0165
	(0.138)	(0.140)	(0.112)	(0.109)	(0.107)	(0.112)	(0.0977)
Reform · High-Tech (R · Tech)		0.273*		0.273*	0.147		0.160
		(0.152)		(0.152)	(0.136)		(0.182)
Log GDP per capita			−0.624	−0.624	−0.624	−0.624	−0.624
			(2.313)	(2.313)	(2.313)	(2.316)	(2.316)
Log GDP			1.023	1.023	1.023	1.023	1.023
			(2.264)	(2.264)	(2.264)	(2.267)	(2.267)
Log real exchange rate			0.0653	0.0653	0.0653	0.0653	0.0653
			(0.151)	(0.151)	(0.151)	(0.152)	(0.152)
Log trade openness			0.590**	0.590**	0.590**	0.590**	0.590**
			(0.203)	(0.203)	(0.203)	(0.203)	(0.203)
Country-industry pair effects	Y	Y	Y	Y	Y	Y	Y
Country-specific time trends	Y	Y	Y	Y	Y	Y	Y
Industry-specific time trends	N	N	N	N	N	Y	Y
Year fixed effects	y	Y	Y	Y	Y	Y	Y
p-Values for H_0: R + R · Tech = 0		0.112		0.159	0.346		0.418
Observations	8464	8464	8464	8464	8464	8464	8464
R-squared	0.672	0.675	0.676	0.679	0.677	0.717	0.717

Note: We define broad offshoring intensity for an industry-country pair as the value of intermediate goods that a US industry imports from all industries of a given country to produce one dollar worth of output. Reform Dummy is equal to one for the year of IPR reform and thereafter (See Table 1 for the timing of reform for each country in our sample). High-tech dummy equals one for patent-sensitive industries and zero otherwise (See Table 2 for the complete list of industry classification). Log GDP and GDP per capita in US$ come from World Development Indicators (WDI) of World Bank. Log of Real Exchange Rate is calculated by using nominal exchanges rate and inflation measures for the US and country c. Log of trade openness is computed as (Exports + Imports)/GDP. In Columns (1) and (2), we exclude country-level control variables. In Columns (3) and (4), we include these controls. In Column (5) High-tech dummy set is constructed by including industry 10, "Drugs, Cleaning and Toilette Preparations" in the high-tech group. In Columns (6) and (7), we include industry-specific time trends. Robust standard errors clustered by country are reported in parentheses. ***, ** and * denote significance at the 1%, 5% and 10% levels.

other years prior to this. Pre4 equals one *only* for 4 years before reform, and likewise for Pre3 and Pre2. Pre1 is omitted as it will serve as the reference point. R0 equals one *at* the year of the reform. Post1 equals one *only* for 1 year after reform, and likewise for Post2, Post3, and Post4. The dummy Post5 equals one for 5 years after reform and thereafter. Table 6 shows that Pre-Reform-Year dummies and their interactions with Tech dummy are mostly negative, and in all cases statistically insignificant. We thus conclude that both broad and intra-industry offshoring

Table 5
How IPR reforms affect intra-industry offshoring ("narrow" offshoring).

Dependent variable	Log US intra-industry offshoring intensity of industry *i* to country *c* at time *t*.						
Sample coverage	1973–2006 (with gaps), 16 countries, 23 US industries						
	(1) Country controls excluded	(2) Country controls excluded	(3) Country controls included	(4) Country controls included	(5) Industry 10 as high-tech	(6) Industry-specific time trends	(7) Industry-specific time trends
Reform dummy (R)	0.00389	−0.211	−0.0224	−0.238	−0.218	−0.0225	−0.144
	(0.175)	(0.180)	(0.149)	(0.152)	(0.161)	(0.150)	(0.138)
Reform · High-Tech (R · Tech)		0.824**		0.824**	0.641**		0.467**
		(0.281)		(0.281)	(0.253)		(0.209)
Log GDP per capita			−1.987	−1.959	−1.973	−1.908	−1.915
			(2.565)	(2.571)	(2.563)	(2.662)	(2.660)
Log GDP			2.065	2.039	2.052	1.980	1.987
			(2.542)	(2.549)	(2.541)	(2.642)	(2.640)
Log real exchange rate			0.00340	0.00497	0.00385	0.00177	0.00193
			(0.254)	(0.255)	(0.254)	(0.269)	(0.269)
Log trade openness			0.345*	0.347*	0.346*	0.359*	0.359*
			(0.185)	(0.186)	(0.185)	(0.195)	(0.195)
Country-industry pair effects	Y	Y	Y	Y	Y	Y	Y
Country-specific time trends	Y	Y	Y	Y	Y	Y	Y
Industry-specific time trends	N	N	N	N	N	Y	Y
Year fixed effects	Y	Y	Y	Y	Y	Y	Y
p-Values for H_0: R + R · Tech = 0		0.052		0.053	0.100		0.222
Observations	8346	8346	8346	8346	8346	8346	8346
R-squared	0.494	0.504	0.494	0.505	0.501	0.617	0.617

Note: We define intra-industry offshoring intensity (also known as narrow offshoring) for an industry-country pair as the value of intermediate goods that a US industry imports from the same exact industry of a given country to produce one dollar worth of output. Reform Dummy is equal to one for the year of IPR reform and thereafter (See Table 1 for the timing of reform for each country in our sample). High-tech dummy equals one for patent-sensitive industries and zero otherwise (See Table 2 for the complete list of industry classification). Log GDP and GDP per capita in US$ come from World Development Indicators (WDI) of World Bank. Log of Real Exchange Rate is calculated by using nominal exchanges rate and inflation measures for the US and country c. Log of trade openness is computed as (Exports + Imports)/GDP. In Columns (1) and (2), we exclude country-level control variables. In Columns (3) and (4), we include these controls. In Column (5), High-tech dummy set is constructed by including industry 10, "Drugs, Cleaning and Toilette Preparations" in the high-tech group. In Columns (6) and (7), we include industry-specific time trends. Robust standard errors clustered by country are reported in parentheses. ***, ** and * denote significance at the 1%, 5% and 10% levels.

intensities fail to show any statistically significant upward trend prior to reform. Similar to Branstetter et al. (2006) we interpret these results as alleviating the possible concerns about IPR reform being endogenous to offshoring intensity.

In addition, we observe a lagged effect of IPR reform on offshoring for both broad and intra-industry offshoring, a reasonable outcome given that it would take some time for such major institutional reform to affect the economy. The effects are observed exclusively in high-tech industries and they appear to kick in about 2–3 years after reform for broad offshoring and about 3–4 years after reform for intra-industry offshoring. To see these, first note that in Table 6, the only significant variables are Post-Reform-Year dummies that are interacted with the Tech dummy (Columns (2) and (4)). Consider first the regressions for broad offshoring intensity in Column (2) of Table 6. The coefficient estimate for the interaction term Post2 · Tech is significant at 5% level and equals 0.143. With every yearly update, the estimate increases, eventually reaching 0.305 for Post5 · Tech. This suggests that high-tech industries increase their broad offshoring intensity relative to low-tech industries in a gradual fashion, beginning with a 15.3% differential 2 years after reform (follows from the coefficient on Post2 · Tech: $e^{0.143}-1$) and then reaching a 35.7% differential by 5 years after reform and thereafter (follows from the coefficient on Post5 · Tech: $e^{0.305}-1$). These results match our main results in Table 4 in that only high-tech industries are affected by IPR reforms when broad offshoring intensity is considered (Table 4, Columns (2) and (4)) but now at higher levels of significance.

Similar to our test of $\beta_2+\beta_3=0$ in Table 4, we test for each post-reform year the null hypothesis that the sum of estimated coefficients on Post-Reform-Year dummy (Post-Year) and Post-Reform-Year interacted with Tech (Post-Year · Tech) is equal to zero. We find that we can reject this hypothesis for 3- and 4-years after reform at 10% significance, and for 5-years after reform at 5% significance. To find the absolute impact on high-tech industries, we add up the coefficient estimates for (Post-Year) and (Post-Year · Tech). For example for 3 years

Table 6
Offshoring with pre and post reform dummies.

Dependent variable	Log US broad offshoring intensity		Log US intra offshoring intensity	
Sample coverage	1973–2006 (complete), 16 countries, 23 industries		1973–2006 (complete), 16 countries, 23 industries	
	(1)	(2)	(3)	(4)
Pre5	−0.0464	−0.0516	−0.104	−0.0817
	(0.132)	(0.126)	(0.180)	(0.206)
Pre4	−0.0623	−0.0611	0.00736	0.0190
	(0.0686)	(0.0706)	(0.102)	(0.103)
Pre3	−0.0779	−0.0698	−0.0123	−0.0161
	(0.0538)	(0.0543)	(0.0729)	(0.0752)
Pre2	−0.0161	−0.0134	0.00498	0.0171
	(0.0344)	(0.0330)	(0.0443)	(0.0478)
R0	0.0470	0.0394	0.0205	0.00637
	(0.0530)	(0.0499)	(0.0620)	(0.0473)
Post1	0.0723	0.0495	0.0351	−0.0143
	(0.0928)	(0.0885)	(0.114)	(0.0966)
Post2	0.0967	0.0595	−0.00222	−0.0542
	(0.100)	(0.0946)	(0.133)	(0.118)
Post3	0.152	0.106	0.0779	−0.0195
	(0.113)	(0.108)	(0.168)	(0.158)
Post4	0.159	0.104	0.0996	−0.0183
	(0.123)	(0.118)	(0.192)	(0.185)
Post5	0.241	0.162	0.0576	−0.153
	(0.148)	(0.140)	(0.175)	(0.150)
Pre5 · Tech		0.0200		−0.0852
		(0.169)		(0.274)
Pre4 · Tech		−0.00464		−0.0443
		(0.0639)		(0.0993)
Pre3 · Tech		−0.0309		0.0133
		(0.0462)		(0.0787)
Pre2 · Tech		−0.0105		−0.0468
		(0.0296)		(0.0648)
R0 · Tech		0.0291		0.0541
		(0.0369)		(0.0777)
Post1 · Tech		0.0875		0.189
		(0.0602)		(0.133)
Post2 · Tech		0.143**		0.200
		(0.0635)		(0.138)
Post3 · Tech		0.176**		0.374**
		(0.0789)		(0.152)
Post 4 · Tech		0.209**		0.452***
		(0.0846)		(0.137)
Post5 · Tech		0.305**		0.808***
		(0.107)		(0.163)
Observations	12512	12512	12360	12360
R-squared	0.525	0.529	0.389	0.400

Note: Broad offshoring intensity for an industry-country pair is defined as the value of intermediate goods that a US industry imports from all industries of a given country to produce one dollar worth of output. Similarly, intra-industry offshoring intensity measures offshoring (again understood as imported intermediate inputs) that takes place within the same industry. Pre5 equals one for 5 years before reform and all other years prior to this. Pre4 equals one only for 4 years before reform. Analogous definitions apply for Pre3 and Pre2. Pre1 is omitted as it serves as the reference point. R0 equals one at the year of the reform. Post1 equals one only for 1 year after reform. Analogous definitions apply for Post2, Post3, and Post4. Post5 equals one for 5 years after reform and thereafter High-tech dummy equals one for high-industries and zero otherwise (See Table 2 for the complete list of industry classification). All specifications include country-industry pair fixed effects and year fixed effects (no country specific linear time trends). They also include country control variables: GDP, GDP per capita, trade openness and real exchange rate. Robust standard errors clustered by country are in parentheses. ***, ** and * denote significance at the 1%, 5% and 10% levels.

after reform, we sum up the coefficient estimates for Post · 3 and Post3 · Tech. This exercise implies that high-tech industries increase their broad offshoring intensity by 32.5% three years after reform (found by $e^{0.106 + 0.176} - 1$) and 36.7% four years after reform (found by $e^{0.104 + 0.209} - 1$), both being marginally significant at 10% level. The increase in broad offshoring by high-tech industries reaches 59.5% five years after reform and thereafter (found by $e^{0.162 + 0.305} - 1$), at conventional statistical significance.

Consider now the regressions for intra-industry offshoring intensity presented in Column (4) of Table 6. The coefficient estimate for the interaction term R3Post · Tech is significant and equals 0.374. With every yearly update, the estimate increases, eventually reaching 0.808 for Post5 · Tech dummy. This suggests that high-tech industries increase their intra-industry offshoring intensity relative to low-tech industries also in a gradual fashion, beginning with a 45.3% differential 3 years after reform (found by $e^{0.374} - 1$) and then reaching a differential of 124.3% by year 5 and thereafter (found by $e^{0.808} - 1$). These results show a pattern consistent with the main results for narrow offshoring in Table 5, where it was stated that high-tech industries increase their intra-industry offshoring intensity by 128% (corresponding to the IPR coefficient of 0.824) following IPR reform. Again, for each Post-Reform-Year, we test the null hypothesis that the sum of estimated coefficients on Post-Reform-Year dummy (Post-Year) and Post-Reform-Year dummy interacted with Tech (Post-Year · Tech) is equal to zero. We find that we can reject this hypothesis for 4 years post reform at 10% significance, and for 5 year post reform at 5% significance. Adding up these coefficient estimates, we find that high-tech industries increase their broad offshoring intensity by 54.3% four years after reform (found by $e^{-0.0183 + 0.452} - 1$) but at marginal statistical significance of 10% level. The increase in offshoring reaches 92.5% five years after reform and thereafter (found by $e^{-0.153 + 0.808} - 1$) at conventional statistical significance. In terms of magnitudes, all of the above results are roughly in line with the difference-in-difference estimators reported in Tables 4 and 5.

We ran robustness checks for these regressions by extending the pre- and post- reform dummies to 9 periods, the maximum time extension without losing any observations in the sample. Recall that the latest reform year is 1997 and our data set ends in 2006. To clarify exposition, define Period(i) for $i \in \{-8, +8\}$ as a dummy variable that corresponds to each pre and post-reform year for a window of 8 years before and after reform. Period (-9) equals one 9 years before reform and all years prior to this. Period $(+9)$ equals one 9 years after reform and thereafter. Fig. 5A and B plot the estimated coefficients on Period(i) interacted with the Tech dummy (Period(i) · Tech) for each pre- and post-reform year, and the corresponding 95% confidence intervals. During the pre-reform years, there is no significant upward or downward trend in offshoring measures in high-tech industries relative to low-tech industries. However, a clear upward trend emerges in the post-reform years with statistical significance two years after reform for broad offshoring and three years after reform for intra-offshoring. The response of intra-offshoring is much stronger than broad offshoring. The results remain very similar to those reported in Table 6.[34] [35]

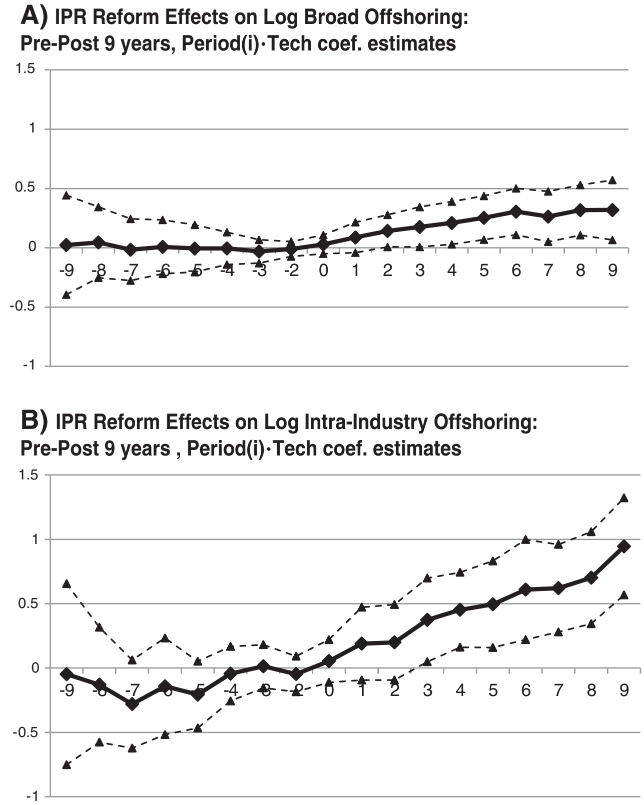

Fig. 5. A: IPR Reform Effects on Log Broad Offshoring: Pre-Post 9 years, Period(i) · Tech coef. estimates. B: IPR Reform Effects on Log Intra -Industry Offshoring: Pre-Post 9 years, Period(i) · Tech coef. estimates.

Note: Broad offshoring intensity for an industry-country pair is defined as the value of intermediate goods that a US industry imports from all industries of a given country to produce one dollar worth of output. Similarly, intra-industry offshoring intensity measures offshoring (again understood as imported intermediate inputs) that takes place within the same industry. We define Period(i) for $i \in \{-8, +8\}$ as a dummy variable that corresponds to each pre and post-reform year for a window of 8 years before and after reform. Period (-9) equals one 9 years before reform and all years prior to this. Period $(+9)$ equals one 9 years after reform and thereafter. We regress broad offshoring intensity on Period(i) and the interaction of Period(i) with Tech dummy. Fig. 5A plots the coefficient estimates for Period(i) · Tech for each year pre- and post-reform. The dotted lines show the 95% confidence intervals. The regression includes country-industry pair fixed effects, year fixed-effects, and country controls: GDP, GDP Per Capita, trade openness, and Real Exchange Rate (no country-specific linear time trends). To construct, Fig. 5B we perform the same exercise but this time use intra-industry offshoring as the dependent variable.

We should, however, remain cautious in emphasizing the estimates in this section since we had to make a number of extra assumptions to construct the input-out coefficients for the missing years. Branstetter et al. (2006, p. 344, Table VI) and Branstetter et al. (2011, p. 32, Fig. 2) also run some similar regressions using as their dependent variables intra-firm royalty payments, log of R&D expenditures of affiliates, non-resident patent filings, and log of affiliate assets. These variables also failed to show clear upward trends prior to reform, but statistically significant increases after reform.

A number of other considerations also help alleviate the concerns about endogeneity. First, one can quickly observe that countries in our sample were at different levels of economic development by the time they implemented IPR reform. This challenges the view that there exists a common threshold level of economic development for IPR reform to materialize. Second, endogeneity becomes a concern if IPR reforms coincide with other concurrent reforms, in particular, those that lead to more integration with the rest of the world. In this case IPR reform dummy would simply proxy for other reforms and the policy implications would be far less clear. To address this issue, we compare the patent reform years of Branstetter et al. (2006) to openness years of Wacziarg and Welch (2008) for our sample of 16 countries. We provide

[34] In Appendix H, we include the figure that shows the estimates and the confidence intervals for the summation of coefficients (Pre9 + Pre9 · Tech), (Pre8 + Pre8 · Tech) and so on until (Post9 + Post9 · Tech).

[35] We investigated further the issue of lagged effects by adding lagged IPR Reform dummies to our baseline specifications (See Appendix C for details). These results also suggest that IPR reforms impact offshoring with a lag. In particular, we find that high-tech industries increase their broad offshoring intensity by around 5.67% two years after reform and thereafter relative to the insignificant increase in low-tech industries by 0.7%. For intra-industry offshoring, the effects are larger and appear to kick in 3 years after reform and also 4 years after reform. More specifically, 3 years after reform and thereafter, high-tech industries increase their intra-industry offshoring intensity by around 19.0% relative to the insignificant decrease in low-tech industries by 1.4%. In addition, 4 years after reform and thereafter, high-tech industries increase their intra-industry offshoring intensity by around 49.3% relative to the marginally significant decrease in low-tech industries by 12.3%.

the exact years in Table J1 of Appendix J. In 14 out of 16 countries, we observe at least a 5-year differential between IPR reform and openness years. In 13 countries, openness precedes IPR reform, and in 8 of them openness precedes IPR reform by at least 15 years. These results cast doubt on the coincidence of IPR reform with other major reforms that lead to more openness. Third, we find that patent-sensitive industries respond to IPR reform by increasing their offshoring relative to the insignificant response of patent-insensitive industries. This differential response is what one would have expected if industries responded to IPR reform and *not* to other concurrent reforms and policy changes. Fourth, Branstetter et al. (2006, pp. 345–347) empirically study the possible link between timing of reform and diplomatic pressure from US. To measure the US diplomatic pressure they used the presence of a country in "Special 301 Watch List" and "Special 301 Priority Watch List" of nations "in which violations are deemed to be especially injurious and where changes in the national IPR environment are a U.S. diplomatic priority." Their estimated hazard model revealed no correlation between the timing of IPR reform and US diplomatic pressure. This result is consistent with the historical evidence provided by Ryan (1998) and Uphoff (1990) and also the interviews of Branstetter and co-authors with managers and legal experts in reforming countries.

6. Conclusion

Over the last three decades, world trade, and particularly, trade in intermediate goods and offshoring between North and South economies have increased dramatically. A large body of the economics literature has proposed several reasons for these trends in trade and offshoring (such as decreases in transportation costs, large improvements on ITC technologies, and growth in income levels). However, only a few studies have empirically investigated the impact of IPR regime changes on trade and multinational activities, and none of them have focused on the response of offshoring (which includes third-party contractual relationships in addition to within-multinational activities).

Our paper empirically assesses the responsiveness of offshoring to Southern IPR reforms. In order to do so, we first construct a measure of US offshoring intensity at the industry level (for 23 manufacturing industries) mapped against the trading partners of US (16 economies). We construct two measures. The first, is broad offshoring intensity, which measures the value of intermediate goods that a US industry imports from *all* industries of a given country to produce one dollar worth of value. The second is intra-industry offshoring intensity, which considers the value of imported goods when US industry imports from the *same* industry abroad. Then, we employ a difference-in-difference approach and regress our offshoring intensity variables on a Reform dummy which identifies the timing of IPR reform for each country. In our specifications, we differentiate between high-tech industries and low-tech industries and control for several country, time and industry characteristics.

We find that following IPR reform, a typical US industry offshoring to our sample of 16 countries does not increase its broad offshoring intensity or its intra-industry offshoring intensity at conventional significance levels. However, a differential response emerges when we distinguish between high-tech and low-tech industries.

In particular, we find strong evidence for high-tech industries substantially increasing their intra-industry offshoring activities and some evidence for the same industries increasing broad offshoring activities following IPR reform. We did not find any statistically significant evidence for increased offshoring by low-tech industries. In both empirical approaches that we utilized, the difference-in-difference specifications and the event study analysis, we find that intra-industry offshoring effects for high-tech industries are much larger and more robust than broad offshoring effects.

Further questions still remain to be explored in the context of IPR reform and offshoring. As noted in Section 2, our IPR reform dummy is a binary variable which obviously misses the possible heterogeneity across countries and also across industries. Future research can investigate this issue by coding up industry-specific patent laws across countries. Another natural follow up to our study can involve looking into the response of offshoring to IPR reform in countries other than the US. For many OECD countries, input–output tables and bilateral trade information exist to render such studies feasible.

Appendix A. Supplementary data

Supplementary data to this article can be found online at http://dx.doi.org/10.1016/j.jdeveco.2014.01.001.

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