

Gnangnon, Sèna Kimm

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Aid for Trade flows, Patent Rights Protection and Total Factor Productivity

Author: Sèna Kimm GNANGNON¹

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Abstract

This study has examined both the effect of Aid for Trade (AfT) flows on the total factor productivity (TFP) level, and the extent to which this effect depends on countries' strength of protection of patent rights. The analysis has used the fixed effects estimator the Method of Moments Quantile Regression approach over a panel dataset of 59 countries and the period from 2002 to 2019. It has established several findings. AfT flows are instrumental in improving productivity in recipient countries, with the largest effect arising from AfT flows for productive capacities. The positive productivity effect of total AfT flows is larger in countries with higher productivity levels. On average over the full sample, total AfT flows exert a larger positive effect on the TFP level in countries that have face higher trade costs, lower innovative output and weaker patent rights protection. Interestingly, increasing the real per capita research and development (R&D) expenditure and concurrently strengthening patent rights laws (to protect the returns on R&D expenditure) result in a larger positive effect of total AfT flows on productivity. In addition, countries with low productivity levels (i.e., those located in lower quantiles) and that increase R&D expenditure in the context of stronger patent rights laws, experience a positive and significant effect of total AfT flows (in particular AfT for productive capacities) on productivity. The magnitude of this positive effect is larger, the lower the quantile of the TFP distribution in which a country is located. These findings have important policy implications.

Keywords: Aid for Trade flows; Intellectual Property Rights; R&D Expenditure; Total Factor Productivity.

JEL Classification: F35; O34; O47.

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¹ Economist at the World Trade Organization (WTO). E-mail for correspondence: kgnangnon@yahoo.fr

1. Introduction

How do Aid for Trade flows affect total factor productivity in developing countries that implement weak patent rights protection? The present analysis aims to address this topic, which has received a little attention in the literature. Total factor productivity (TFP) is the residual fraction of the Gross Domestic Product (GDP) that is not attributable to the accumulation of factors of production, including physical and human capital (e.g., Barro and Sala-i-Martin 2004; Bosworth and Collins, 2003).

The Members of the World Trade Organization (WTO) pay special attention to the participation of developing countries in the global trading system (e.g., WTO, 2014, 2021) as these countries (and most notably least developed countries² - LDCs - among them) face huge trade-related infrastructure and capacity constraints that inhibit their participation in international trade (e.g., Hallaert, 2010; Hallaert and Munro, 2009). To help overcome these hurdles to their engagement in international trade, WTO Members launched the Aid for Trade (AfT) initiative at the 2005 WTO's Hong Kong Ministerial Conference. Paragraph 57 of the Declaration issued at the end of this Ministerial Conference (WTO, 2005) provides that "*Aid for Trade should aim to help developing countries, particularly LDCs, to build the supply-side capacity and trade-related infrastructure that they need to assist them to implement and benefit from WTO Agreements and more broadly to expand their trade.*"

AfT flows are part of the official development assistance (ODA³) allocated for promoting developing countries' participation in international trade. The launch of the AfT initiative has led to a wealth of studies⁴ on its economic (of which trade, including both imports but most importantly exports) effects and social effects. Many of these works have documented that AfT flows help reduce trade costs and foster recipient countries' export performance (e.g., Busse et al., 2012; Cali and te Velde, 2011; Tadesse et al., 2019; Vijil and Wagner, 2012). Despite the importance of productivity improvement for economic growth and development, few studies have explored the effect of development aid on productivity (e.g., Alvi and Senbeta, 2012; Economides et al., 2008; Groß and Danzinger, 2022; Herzer and Morrissey, 2013) and none of these studies have explored the effect of AfT interventions on productivity. Economides et al. (2008) have found that development aid encourages rent-seeking behaviour at the detriment of productive activities. In a similar vein, Alvi and Senbeta (2012) have obtained that development aid (in particular multilateral aid) reduces TFP. According to Herzer and Morrissey (2013), development aid affects negatively productivity if it favours poor governance. In a recent study, Groß and Danzinger

² LDCs have been designated as such (and the group of LDCs regularly updated) by the Committee on Development Policy of the United Nations using three criteria, including the income, the human assets, and the Economic and Environmental Vulnerability. This category of countries represents the poorest countries in the world that are concurrently the most vulnerable ones to exogenous economic and financial shocks, as well as to environmental shocks. Additional information on the LDCs, including the list of countries included in this category are available online at: <https://www.un.org/ohrrls/content/least-developed-countries>

³ ODA is the government aid that promotes and specifically targets the economic development and welfare of developing countries. The concept of "ODA" was adopted by the Development Assistance Committee (DAC), as the "gold standard" of foreign aid in 1969, and since then, it has remained the main source of financing for development aid (e.g., OECD, 2021). ODA flows are provided by donors to developing countries either bilaterally or through the multilateral institutions such as the World Bank, the World Trade Organization and the United Nations as well as regional development banks. For further information on the definition of the concept of ODA, see the website of the Organisation for Economic Co-operation and Development (OECD) at: <https://www.oecd.org/dac/financing-sustainable-development/development-finance-standards/official-development-assistance.htm>

⁴ Benziane et al. (2022) have provided a survey on the effects of AfT flows.

(2022) have used long-time-period data (over the period 1973-2009) to uncover empirically that development aid (including both grants and bilateral aid) reduces the aggregate productivity level, and so in all quantiles of the TFP distribution. However, this effect becomes statistically nil after 2000. The authors have explained this outcome by the improvement of aid effectiveness through the harmonization of donor practices and activities in their operational policies, and procedures, as well as by the improvement in the monitoring and evaluation of projects at the sectoral level, which have contributed to enhancing the efficiency of development projects.

Concurrently, there is a global trend of strengthening intellectual property rights (IPR) that arises firstly from the requirements by the WTO's Trade-Related Intellectual Property (TRIPS) Agreement that governments should implement minimum standards to ensure the protection of fellow WTO member states' intellectual property. The stated objective of the Agreement is to promote innovation and facilitate technology diffusion for the public's welfare. The second cause of the tendency for countries to implement stronger intellectual property laws is the belonging of countries to bilateral and regional trade and investment treaties that impose standards of IPR protection that go beyond the ones of the WTO's TRIPS Agreement (e.g., Maskus, 2015; Thrasher, 2021; UNCTAD, 2007). The literature on the effect of the strengthening of intellectual property (IPR) rights on productivity in developing countries at the aggregate level is also relatively limited (e.g., Coe et al., 2009; Krammer, 2015; Habib et al., 2019; Su et al., 2022). While the majority of these studies have reported a positive effect of stronger intellectual property laws on productivity (e.g., Coe et al., 2009; Krammer, 2015; Habib et al., 2019), the work by Su et al. (2022) has revealed the existence of a U-shaped relationship between IPR protection and total factor productivity in developing countries.

As indicated above, to the best of our knowledge, no study has investigated the effect of AfT flows (which essentially target trade-related productive sectors) on TFP. The present analysis aims to fill this gap in the literature by linking the two above-mentioned strands of the literature, namely the literature on the effect of development aid on TFP, and the literature on IPR protection on TFP. Specifically, the paper investigates the effect of AfT flows on the aggregate TFP level, and whether this effect (if any at all) depends on the strength of IPR protection in AfT recipient countries.

The rationale for investigating this topic is as follows. Lower trade costs brought about by higher AfT flows (e.g., Busse et al., 2012; Calì and te Velde, 2011; Tadesse et al., 2019; Vijil and Wagner, 2012) can improve TFP given that the fall in trade costs is TFP enhancing (e.g., Abeberese and Chen, 2022; Bernard et al. 2006a; Ferreira and Trejos, 2011; Miroudot et al., 2012). More specifically, the trade costs reduction induced by higher AfT flows can encourage imitation or innovation, which in turn, could improve the TFP level in recipient countries. On the other side, part of AfT flows can be used to import intermediate and capital goods that embody the knowledge and technology that firms do not possess and that could be used to enhance innovation, which is critical for TFP improvement. AfT flows is unlikely to induce greater TFP without investment in research and development (R&D) - whose returns need to be protected by intellectual property laws - that would enhance firms' capacity of absorbing the external knowledge and technology.

The empirical analysis has covered 59 developing countries (that are AfT recipients) over the annual period from 2002 to 2019. The within fixed effects estimator (with the Driscoll and Kraay (1998) technique) and the Quantile via Moments proposed by Machado and Santos Silva

(2019) have been used to carry out the empirical analysis. Several findings emerge from the analysis. First, total AfT flows influence positively the level of TFP, including in countries that implement effectively weak IPR. The positive effect of total AfT flows on the TFP level is larger in countries that enjoy higher TFP levels than in those with relatively lower TFP levels. Total AfT flows exert a larger positive effect on the TFP level in countries that face higher trade costs, lower innovative output and weaker patent rights protection. R&D expenditure mediates the interaction effect of total AfT flows and patent rights protection on the TFP level. Specifically, countries that endeavour to increase their R&D expenditure while concurrently strengthening their patent rights laws (to protect the returns on these R&D expenditure) enjoy a larger positive effect of total AfT flows on the TFP level. This is particularly the case for countries with low TFP levels, notably those situated in the lower quantiles of the TFP distribution.

The remainder of the paper is organized as follows. Section 2 presents a discussion on how AfT flows and IPR protection can affect the TFP level, and emphasizes the extent to which the effect of AfT flows on productivity can depend on the level of IPR protection strength. Section 3 presents the empirical strategy, including the model specification to address empirically the issue at hand, and the econometric approach to estimate this model. Section 4 interprets the estimations' outcomes, and Section 5 deepens the analysis. Section 6 concludes.

2. Theoretical discussion

This section builds on relevant strands of the literature to discuss how AfT flows and IPR protection can affect TFP in recipient countries. Sub-section 2.1 discusses how AfT flows can affect the TFP level, and sub-section 2.2 lays out a discussion on how the protection of IPRs affect TFP. Sub-section 2.3 discusses the extent to which the effect of AfT flows on TFP depends on the strength of IPRs protection, and sub-section 2.4 lays down a discussion on the role that R&D expenditure could potentially play in the interaction effect of AfT flows and IPR protection on productivity.

2.1. Effect of AfT flows on TFP

Studies on the effect (including trade effects) of AfT flows have used three main categories of ODA⁵ flows - identified as such by the OECD - to form total AfT flows (e.g., OECD/WTO, 2007, 2011, 2019). These include AfT flows for building economic infrastructure, AfT flows for strengthening productive capacities, and AfT flows geared towards trade policy and regulation. The first of these categories, namely AfT for economic infrastructure purport to develop or enhance hard and soft infrastructure⁶ in recipient countries. AfT for productive capacities aims to enhance the production and export capacity of micro, small and medium-sized enterprises (MSMEs) operating in developing countries, improve their competitiveness in the international trade market, and ultimately improve their capacity to meet demands for goods and services in the international market. AfT for productive capacities target a wide range of productive sectors, including banking and financial services, business and other services, agriculture, fishing, industry, mineral resources and mining, and tourism.

⁵ Appendix 1 provides details on the sectoral coverage of each of these three major categories of AfT flows.

⁶ Hard infrastructure can include highways, railroads, ports, etc., and soft infrastructure refers to transparency, customs efficiency, institutional reforms (Portugal-Perez and Wilson, 2012: p 1296).

AfT interventions for trade policy and regulation have several objectives. They aim to help policymakers in recipient countries improve their capacity to participate in trade negotiations, including at the multilateral level (at the WTO), better understand and implement WTO Agreements and Decisions, and develop the requisite institutions and the regulatory framework needed to improve their participation in international trade. In this regard, they help policymakers of developing countries design trade policy and trade-related institutions in a manner consistent with WTO Agreements and Decisions. This category of AfT flows has also been instrumental in facilitating the cross-border movement of trade flows, through the enhancement of border and transport efficiency, notably by streamlining the time, cost, and number of documents necessary for export and import procedures. Finally, AfT flows related to trade policy and regulation has a trade-related adjustment component that compensates less productive firms for the losses incurred as a result of trade liberalization reforms. It is worth pointing out here that this specific component of AfT flows can enhance the productivity of existing productive MSMEs, and avoid that least productive MSMEs exit the market during the trade liberalization reform process, while eventually improving their productivity so as to increase their market share.

AfT flows can affect productivity through their trade costs reduction effect insofar as lower trade costs leads to the TFP improvement (e.g., Abeberese and Chen, 2022; Bernard et al. 2006a; Ferreira and Trejos, 2011; Miroudot et al., 2012). In fact, on the one hand, the literature has well documented theoretically and empirically that AfT flows are instrumental in reducing trade costs⁷ in recipient-countries (e.g., Busse et al., 2012; Cali and te Velde, 2011; Gnangnon, 2018; OECD/WTO, 2015; Tadesse et al., 2017; Tadesse et al., 2019; Tadesse et al., 2021; Vijil and Wagner, 2012). On the other hand, lower trade costs contribute significantly to productivity improvement. In fact, lower trade costs enhance competition and may lead plants to improve their productive efficiency (e.g., Lawrence, 2000) and change their product mix (this is the so-called intra-plant reallocation - e.g., Bernard et al., 2006b). The decline in trade costs leads to an improvement in the industry productivity through the reallocation of economic activity towards high productive plants. It allows high-productivity plants to expand by entering into export markets or expanding their sales to foreign markets, and forces least productive firms and non-exporting firms to shut down (e.g., Bernard et al., 2003; Melitz, 2003). Bernard et al. (2006a) have found that industries that experience relatively large declines in trade costs (including tariff rates and transport costs) exhibit relatively high gains in the overall productivity growth. The theoretical work by Ferreira and Trejos (2011) has also revealed that improving trade, including through reducing barriers to trade leads to a more efficient resources allocation across sectors, and boosts productivity. In particular, the gains from trade for some poor countries range between 50% to 100% of TFP. According to Abeberese and Chen (2022), the pro-competitive effect of trade costs reduction in developing countries leads to an improvement in firms' productivity because firms reduce their product scope and focus on the products in which they are most efficient. The authors have found for India that an exogenous reduction in intranational trade costs (through a highway construction project) has led to a reduction in firms' product scope and an increase in their productivity. After taking into account input price differences, De Loecker et al. (2016) and Brandt

⁷ Trade costs can be considered here in a broader sense as all the costs incurred in delivering a good from the point of production to the final user. These include transport and time costs, tariff and non-tariff policy barriers, information costs, contract enforcement costs, regulatory and compliance costs, and distribution costs (Anderson and van Wincoop, 2004, p. 692).

et al. (2017) have shown that tariff liberalization can raise firm productivity. More recently, Grieco et al. (2022) have documented that the input price effects of tariff liberalization represent a distinct and important source of gains from tariff liberalization. They have shown that the mild short-term effect of tariff liberalization is amplified in the long run by the induced trade participation, thereby leading to an even higher productivity and lower input prices. Miroudot et al. (2012) have obtained that reducing trade costs by 10 percent leads to an improvement of TFP by around 0.5 per cent in the services sector, which is an effect similar to that in the goods sector.

Against this backdrop, we postulate the following hypothesis (Hypothesis 1).

Hypothesis 1: By helping to reduce trade costs, higher AfT flows would lead to a greater improvement in productivity, notably in countries that face higher trade costs. In other words, not only would AfT flows enhance productivity improvement (**hypothesis 1a**), but these capital inflows would also exert a larger positive TFP effect in countries that face higher trade costs (**hypothesis 1b**).

On another note, AfT flows can also affect indirectly TFP through the imitation/innovation channel, insofar as imitation (and innovation) affects positively TFP in developing countries (e.g., Crespi and Zuniga, 2012; Guo et al., 2015; Hobday, 1995; Navarro et al., 2010; Liao, 2020; Madsen et al., 2010). Lower trade costs encourages technology adoption and stimulates innovation (e.g., Bloom et al. 2013; Coelli et al. 2022; Iacovone, 2012; Impullitti and Licandro, 2018; Long et al. 2011; Navas, 2015), which allows firms to create and sustain their competitive advantage (Barney, 1991; Drucker, 1985). For example, the theoretical analysis provided by Long et al. (2011) has shown that when trade costs are low, trade liberalization increases aggregate R&D and when trade costs are high, trade liberalization decreases aggregate R&D. Iacovone (2012) has found that the strong positive productivity growth effect (for Mexican firms) of the trade liberalization under the North American Free Trade Agreement is attributed more importantly to firms' innovative and managerial efforts. Bloom et al. (2013) have shown that low-cost import competition can raise the innovation rate if factors of production are trapped inside a firm. According to Navas (2015), initially less competitive sectors experience a greater innovation and a higher productivity growth when countries move from autarky to free trade. Impullitti and Licandro (2018) have shown that the reduction of trade costs leads to an increase in the average size of surviving firms and their aggregate productivity. In turn, the increase in surviving firms' size stimulates costs-reducing innovation, which leads to faster productivity growth. The analysis by Shu and Steinwender (2019) has found, *inter alia*, that trade liberalization promotes innovation in emerging countries. In a similar vein, greater exposure to international markets through higher exports provides incentives for innovation (Akcigit and Melitz, 2022). Likewise, according to Perla et al. (2021), the decline in trade barriers encourages a faster technology adoption. Coelli et al. (2022) have obtained empirically that tariff cuts exert a large positive effect on innovation (measured by patent data).

In light of the foregoing, we argue that as AfT flows reduce trade costs, and hence encourages imitation/innovation, and it will ultimately lead to a higher TFP level. Therefore, we postulate the following hypothesis (Hypothesis 2).

Hypothesis 2: AfT flows will lead to a greater productivity improvement in countries that have lower levels of innovation output as these countries are likely to face higher trade costs. In addition, the positive effect of AfT flows on productivity would be larger, the lower is the level of innovation output.

2.2. Effect of IPR protection on TFP

The WTO TRIPS Agreement, which entered into force in 1995 (at the inception of the WTO) has established a set of minimum standards of protection to be implemented by each government so as to protect the intellectual property of fellow WTO member states. The objective of the TRIPS Agreement is set out in Article 7, and states that: "*The protection and enforcement of intellectual property rights should contribute to the promotion of technological innovation and to the transfer and dissemination of technology, to the mutual advantage of producers and users of technological knowledge and in a manner conducive to social and economic welfare, and to a balance of rights and obligations.*" Yet, the Agreement contained some flexibilities that apply to all WTO Members to promote development and protect public interest, but LDCs have been granted more generous flexibilities in view of their limited resource and capacity constraints to implement the Agreement. The first major LDC-specific flexibility is the transition period accorded to LDCs for the implementation of the majority of provisions of the Agreement. Since the entry into force of the Agreement, this 'general' transition period has been extended three times, the current extension lasting until 1 July 2034, or until a member graduates from LDC status, whichever occurs earlier (WTO, 2022). The second main flexibility in favour of LDCs in the TRIPS Agreement takes the form of a transition period during which LDCs are exempted from providing patent protection and undisclosed information for pharmaceutical products. This period is to expire on 1 January 2033 - or until a LDC WTO Member graduates from the LDC status - whichever is earlier (WTO, 2022).

However, LDCs may not fully enjoy the benefits of these flexibilities as they are parties to bilateral, regional and non-reciprocal trade and investment agreements that impose higher standards of IPR protection (the so-called TRIPS-Plus provisions) than the ones enshrined in the multilateral TRIPS Agreement (e.g., Maskus, 2015; Mitchell et al., 2013; Syam and Syed, 2023; Thrasher, 2021; UNCTAD, 2007). For example, some LDCs have implemented stronger patent laws in deviation from the general transition period and from the pharmaceutical-related waiver described above (e.g., Maskus, 2015; Mitchell et al., 2013; Syam and Syed, 2023).

The theoretical rationale for the positive effect of stronger IPR protection (in particular, stronger patent laws) on TFP is that a greater IPR protection lays a fertile ground for the development of R&D activities by securing the returns to R&D investment by the innovator, with a view to stimulating innovation (e.g., Mansfield, 1985). However, even though imitation can be costly⁸, it is pervasive in developing countries, particularly LDCs among them (e.g., Coe et al., 1997; Liao, 2020; UNCTAD, 2007). The extent of imitation depends on a range of factors such as the specific characteristics of the industry concerned (Mansfield, 1986), competitors' R&D investment and domestic firms' absorptive capacity (e.g., Cohen and Levinthal, 1989), as well as the tacitness, and circumstantial sensitivity of technology (e.g., Evenson and Westphal, 1995).

The theoretical argument that stronger intellectual property laws promote innovation has not always been supported by the historical and empirical evidence (e.g., Maskus, 2012; Moser, 2013). While at best, the strengthening of intellectual property laws (including patent laws) encourages innovation in developed countries (e.g., Maskus, 2012; Maskus et al., 2019), it is still uncertain

⁸ According to Mansfield et al. (1981) the ratio of imitation costs to innovation costs is high and reaches 0.65, and the ratio of the imitation time to the innovation time amounts to 0.70. The authors have concluded that information leaks from competitors' innovation may not immediately result in product imitation.

whether this finding applies to developing countries (see Sharma et al. 2018 for a literature review). The effect of IPR protection strengthening on innovation in developing countries depends on several factors, including countries' current stage of development and the specific characteristics of industries (e.g., Sharma et al. 2018), and may eventually be U-shaped (e.g., Chen and Puttitanun, 2005; Hwang et al., 2016). Nevertheless, there seems to be an emerging consensus that in view of the weak absorptive capacities (e.g., weak human capital, financial resources and weak institutions) of poor countries, including LDCs, stronger intellectual property laws are likely to hinder rather than encouraging innovation (e.g., Auriol et al., 2023; Goldberg and Pavcnik, 2007; Madsen et al., 2010; Su et al., 2022; UNCTAD, 2007).

Few studies have investigated the effect of IPR protection on TFP at the country level (e.g., Coe et al., 2009; Krammer, 2015; Habib et al., 2019; Su et al., 2022). While all three studies have uncovered a positive effect of stronger IP laws on TFP, the findings by Su et al. (2022) are mixed. Coe et al. (2009) have obtained for a sample of 24 advanced economies that stronger patent laws enhance productivity, including by encouraging entrepreneurial R&D activities that result in larger quality improvements for a given R&D effort. On another note, the authors have also uncovered a positive effect of domestic and foreign R&D capital stocks on TFP. Krammer (2015) has used a sample of 20 developed countries in Europe, and 27 transition economies, and obtained that good institutions (among which stronger protection of IPR) exert a positive effect on productivity. Habib et al. (2019) have observed for 16 developing countries⁹ that stronger IPR protection (and R&D expenditure) have influenced positively changes in TFP. Sweet and Eterovic (2019) have provided empirical evidence that to improve TFP, countries need to develop their ability to adapt, replicate and diffuse along the international productive chain, rather than relying on the strengthening of patent rights protection (to promote innovation). The analysis by Su et al. (2022) has covered two different set of countries and time periods, with a maximum of 95 countries that include low-income countries, developed countries and a set of developing countries that does not include low-income countries. After controlling for the effect of the R&D effort on the TFP level, the authors have established empirically the existence of an inverted U-shaped effect of stronger intellectual property laws on TFP in both developed and developing countries. However, for low-income countries, weak IPR protection leads to the improvement of TFP. Incidentally, there is really no significant effect of R&D effort on TFP across the various samples analysed by the authors.

In the present analysis, we can postulate that the effect of IPR protection on TFP in developing countries would depend on the innovation capacity of these countries. Stronger intellectual property (e.g., patent) laws are likely to hurt TFP in countries with weak innovative capacity (e.g., LDCs), and enhance TFP in developing countries with a relatively greater innovation (or eventually imitation) capacity. Meanwhile, the strengthening of intellectual property laws in LDCs may lead to a higher TFP if concurrently, these countries (e.g., Bangladesh) endeavour to improve their imitation capacity, for example through a higher R&D expenditure. For example, the share of R&D expenditure in GDP exceeds 0.5% in many LDCs despite their low imitation abilities (e.g., Campi et al. 2019). Overall, the direction of the effect of the strengthening of IPR protection on TFP is a priori unknown, and is to be determined empirically (**Hypothesis 3**).

⁹ These countries include the BRICs (Brazil, Russian Federation, India and China) and Central and Eastern European (CEE) countries.

This hypothesis leads to the theoretical discussion concerning on the extent to which the effect of AfT flows on the TFP level depends on the strength of IPR protection in developing countries.

2.3. How does the effect of AfT flows on productivity depends on the strength of IPR protection?

As hypothesized above (see **hypothesis 2**), AfT flows lead to TFP improvement in countries that have lower innovation output because such countries face higher trade costs. Therefore, one could expect that higher AfT flows would exert a larger positive effect in countries with lower innovation output.

Against this background, we postulate the following hypothesis (hypothesis 4).

Hypothesis 4: AfT flows would exert a larger positive effect in countries with lower innovation output, with the magnitude of this positive effect increasing as the level of output innovation decreases.

It follows from this hypothesis that countries with higher trade costs, and hence lower innovative output, are likely to have lower IPR protection levels. This is simply because as noted above, the strengthening of IPR protection aims to stimulate innovation by protecting the returns on innovators' investments. We deduce the following hypothesis (hypothesis 5).

Hypothesis 5: AfT flows would be associated with a higher productivity improvement in countries that have a weak IPR protection level than in those with a greater level of IPR protection, and the weaker the IPR protection degree, the larger would be the positive effect of IPR on TFP.

2.4. The role of R&D expenditure in the joint effect of AfT flows and IPR protection on productivity

We have previously argued that AfT flows would lead to TFP improvement in countries that have low levels of innovation output because such countries face high trade costs (see Hypothesis 4). At the same time innovation output is determined by several factors, including primarily the innovation effort or innovation investment, also referred to as innovation input¹⁰ (e.g., Cohen and Levinthal, 1989; Crespi and Zuniga, 2012; Griffith et al. 2003; Le, 2020; Santos et al., 2014). Innovation effort encompasses both internal knowledge and the capacity to absorb the external knowledge and technology and is, in this regard, likely to be influenced by the strength of IPR protection.

Importation of intermediate and capital goods (e.g., machinery and equipment) plays a critical role in developing countries' productivity improvement, as it provides domestic firms with access to the technology, stock of knowledge and ideas that they do not have, and hence helps improve their performance (e.g., Amity and Konings, 2007; Coe and Helpman, 1995; Criscuolo et al., 2005; Goldberg et al. 2010; Halpern et al., 2015; Kasahara and Rodrigue, 2008; Kugler and Verhoogen, 2009; Massini et al., 2023; Pavcnik, 2002). The empirical analysis by Addison (2003) has shown that the largest source of productivity gain in developing countries is provided by the imitation of intermediate goods from developed countries. In fact, firms can learn and improve their performance and productivity by importing intermediate products and capital goods (e.g., machinery and equipment) that embody technological knowledge (e.g., Coe and Helpman, 1995;

¹⁰ See for example, the literature survey by Le (2019, 2020).

Halpern et al. 2015). AfT flows can facilitate access to this external technology and knowledge, not only by facilitating imports of intermediate products and capital goods (thanks to its trade costs reduction effect), but also by providing recipient countries with financial means to import these goods. In fact, a number of studies have reported a positive effect of total AfT flows (including the components of the latter) on imports by recipient countries, notably from donor-countries (e.g., Helble et al. 2012; Hühne et al., 2014; Lemi, 2007; Pettersson and Johansson, 2017). Furthermore, AfT interventions promote import diversification (Ly-My, 2021), especially in countries that diversify their export products and further liberalize their trade policies (e.g., Gnangnon, 2021).

Once firms have access to the external technology and knowledge through importation, they need to be capable of using them. In fact, developing countries' firms tend to imitate or adapt external knowledge sources to their local realities so as to develop innovation outcomes rather than creating their own new knowledge (e.g., Chudnovsky et al., 2006). Hence, to fully benefit from this external knowledge, i.e., to absorb and exploit the external knowledge, firms need to develop or strengthen their absorptive capacity, including through R&D investment (e.g., Cohen and Levinthal, 1989, 1990; Griffith et al., 2003; Li et al., 2010). Absorptive capacity improvement arises from investments in intangible assets, including through R&D expenditure, and plays a major role in countries' performance (e.g., Cohen and Levinthal, 1989; Corrado et al., 2009; Haskel, 2015), and industries and firms' performance (e.g., Chappell and Jaffe, 2018; Griffith et al., 2003; Maskus et al., 2019; Yang et al., 2018).

Investment in R&D does not only generate innovations, but it also allows firms to learn from competitors and extra-industry knowledge sources (e.g., Cohen and Levinthal, 1989; Griffith et al., 2003). Learning and absorptive capacity (through for example, R&D investment) co-move and reinforce each other (e.g., Barkema and Vermeulen, 1998). For example, Cohen and Levinthal (1989: p569) have considered that "absorptive capacity" or "learning capacity" differs from the "learning-by-doing" and encompasses not only a firm's ability to imitate new process or product innovations, but also its ability to exploit outside knowledge of a more intermediate sort (e.g., basic research findings) that provides the basis for subsequent applied research and development. This is particularly relevant for developing countries, and poorest countries (including LDCs) among them. Cohen and Levinthal (1989) have provided support for the argument that R&D promotes innovations and helps develop firms' 'learning' or 'absorptive' capacity, i.e., their ability to identify, assimilate, and exploit others' discoveries. Griffith et al. (2003) have shown that R&D investment affects both innovation and absorptive capacity, and contributes to explaining cross-country productivity¹¹ differences.

Incidentally, it is worth noting that in a recent study, Soete et al. (2022) have observed empirical evidence for OECD countries that public and private domestic stock of R&D investment are strongly complementary, and this complementarity exerts a strong positive effect on TFP. While this study has focused on advanced economies, it sheds light on the fact that public

¹¹ The positive effect of R&D expenditure on TFP in developing countries has been documented in the literature (see for example Coad, 2011; Bravo-Ortega and Marín, 2011; Madsen et al., 2010). More generally, many works, including those that have relied on the approach pioneered by Crepon et al. (1998) have demonstrated that R&D expenditure is critical for innovation and productivity performance (see for example Hall, 2011, for a literature survey on the matter).

R&D can complement private R&D, that is, R&D investment by firms in strengthening firms' innovative efforts.

Overall, at the aggregate level, R&D investment can help countries develop their capacity to assimilate and exploit new knowledge, and allow firms to gain a first-mover advantage in exploiting new technologies generated by universities, government laboratories and other competitors. In particular, in developing countries and poor countries where absorptive capacity is weak, R&D investment in basic research is needed to take full advantage of spillovers from a competitor's innovation. This implies that these countries' innovation effort should encompass not only the extent of access to external sources of knowledge and technology, but also R&D investment to absorb this external knowledge. These two facets of innovation investment are complementary in enhancing firms' innovation output and performance (e.g., Baldwin and Hanel, 2003; Chudnovsky et al., 2006; Hall et al., 2009; Le, 2020; Lewin et al., 2011; MacGarvie, 2006; Massini et al., 2023; Schweisfurth and Raasch, 2018; Veugelers, 1997). In a recent study, Massini et al. (2023) have used data on Ukrainian firms to provide empirical evidence that private-owned enterprises benefit strongly from the complementarity arising from the assimilation and integration of knowledge from international external sources (especially international trade) and internal knowledge (through R&D investment), especially when their trade partners reside in advanced markets. The complementarity between participation in international trade (for example through imports) and R&D investment is particularly relevant for improving companies' productivity in developing countries where absorptive capacity is relatively weak (e.g., Anand et al., 2021).

In the present analysis, AfT flows contribute to facilitating access to external knowledge through their trade costs reduction effect, as well as their positive effect on imports, thereby enhancing the external knowledge component of innovation effort. On the other hand, an increase in R&D expenditure will strengthen the absorptive capacity component of developing countries' innovation effort. Thus, both higher AfT flows and R&D expenditure could spur innovation effort and help countries enjoy - at the aggregate level - an improvement in productivity. However, this effect is unlikely to materialize in the presence of intellectual property laws that do not protect the returns on R&D expenditure. For example, Yang and Maskus (2009) have shown theoretically that strengthening IPR protection in developing countries promotes technology transfers from the Northern firm through licensing, and reduce the Southern firm's marginal production costs, related to the degree of know-how absorbed, as well as the cost of technology transfer. This results in an improvement in the Southern firm's competitiveness in the international markets and the expansion of its exports, especially if domestic firms have strong capacities to absorb and implement available international technologies.

The previous discussion has highlighted the importance of the innovation effort in a context of a relatively strong intellectual property laws for encouraging imitation and innovation, and fostering TFP. Therefore, one could expect that AfT flows (that could help access the external knowledge and technology) will enhance TFP in countries that increase R&D investment (to increase firms' absorptive capacity) while concurrently strengthening their intellectual property laws (including patent laws) to secure returns to the R&D expenditure.

We formulate the following hypothesis (**Hypothesis 6**).

Hypothesis 6: AfT flows are associated with an increase in the TFP in countries that experience simultaneously an increase in R&D expenditure and a greater IPR protection. In these

countries, the greater the combined level of R&D expenditure and IPR protection, the larger will be the positive effect of AfT flows on TFP.

3. Empirical strategy

This section first presents the model specification underpinning the analysis of the extent to which the effect of AfT flows on TFP depends on the strength of IPR (see sub-section 3.1). It, then presents the econometric approach used in the analysis (see sub-section 3.2).

3.1. Model specification

To explore empirically the effect of AfT flows on TFP, and whether this effect depends on the strength of IPR protection, we consider a baseline model specification where the dependent variable is the indicator of TFP, and the key variables of interest are the indicator of total AfT flows (or each of its components). Control variables are drawn from the relevant literature (e.g., Alvi and Senbeta, 2012; Coe et al., 2009; Groß and Danzinger, 2022; Madsen et al., 2010; Sweet and Eterovic, 2019; Su et al., 2022) and include other development aid flows than AfT flows, human capital, the inflation rate, government consumption, foreign direct investment (FDI) inflows, the population growth rate, the terms of trade, and the quality of institutions.

The baseline model specification takes the following form:

$$TFP_{it} = \alpha_0 + \alpha_1 \text{Log}(AfT)_{it} + \alpha_2 \text{PRI}E_{it} + \alpha_3 \text{Log}(NonAfT)_{it} + \alpha_4 \text{HUM}_{it} + \alpha_5 \text{POPGR}_{it} + \alpha_6 \text{INFL}_{it} + \alpha_7 \text{GCONS}_{it} + \alpha_8 \text{FDI}_{it} + \alpha_9 \text{TERMS}_{it} + \alpha_{10} \text{INST}_{it} + \gamma_t + \mu_i + \epsilon_{it} \quad (1)$$

The subscripts i and t stand respectively for a country, and a sub-period. The panel dataset is unbalanced, and has been built on the basis of data availability. It covers 59 countries and the annual period from 2002 to 2019.

α_0 to α_{10} are parameters that will be estimated later in the analysis. μ_i are countries' (time invariant) fixed effects, and γ_t stand for sub-period dummies that reflect global factors that affect TFP simultaneously in all countries. ϵ_{it} is an error-term. The variables "AfT" and "PRIE" represent respectively the indicator of AfT flows (i.e., total AfT flows or the components of the latter), and the indicator of effective patent protection rights used as a proxy for the effective enforcement of the protection of IPRs (e.g., Hu and Png, 2012; Liu et al., 2021; Maskus and Yang, 2018).

The dependent variable "TFP" is the total factor productivity, and is obtained as the residual fraction of the Gross Domestic Product (GDP) that is not attributable to the accumulation of factors of production, including physical and human capital. It is measured by the TFP level at current purchasing power parity (USA=1), and in this regard, shows relative TFP across countries. Data on TFP is drawn from the Penn World Tables 10.01 (see Feenstra et al., 2015). This indicator has been used in many studies in the empirical literature, including in works that have examined the effect of IPR protection on TFP (e.g., Sweet and Eterovic, 2019; Su et al., 2022). It has been calculated using a Cobb-Douglas production function, which maps factors into inputs.

The indicator "AfT" is the real gross disbursements of AfT flows, expressed in constant prices 2020, US Dollar. It can be the total AfT flows (denoted "AfTTOT"), or one of its three main components, namely AfT flows for the build-up of economic infrastructure ("AfTINF"),

AfT flows for fostering productive capacities ("AfT_{PR}"), and AfT flows related to trade policy and regulation ("AfT_{POL}"). Likewise, the variable "NonAfT" represents the development aid flows allocated to other sectors in the economy than the trade sector. It has been computed as the difference between the gross disbursements of total ODA and the gross disbursements of total AfT, both being expressed in constant prices 2020, US Dollar. AfT variables and the gross disbursements of total ODA were extracted from OECD/DAC-CRS¹² database.

The index of patent rights (PRI) strength used to compute the variable "PRIE" is drawn from Park (2008) (see also Ginarte and Park, 1997) and has been widely used in the empirical literature on the determinants and impacts of IPR protection (e.g., Auriol et al., 2023; Chu et al., 2014), in particular on the literature concerning the effect of IPR protection on the TFP level at the country-level (e.g., Sweet and Eterovic, 2019; Su et al., 2022). The index "PRI" was computed as the unweighted sum of scores of the following five components whose values range between 0 and 1: the patent protection duration relative to the international standard; the subject matter that is patentable (or not unpatentable); the membership in international IPR agreements; the mechanisms available for patent enforcement; and how limited (or less restricted) the patenting exceptions are (for example, any requirement to practice the invention or license the patents to third parties). The score of the overall index of patent rights protection varies from 0 to 5, with higher values indicating stronger levels of patent rights protection. Data on the indicator "PRI" is available every five years, and covers in the present analysis the years 2005; 2010; and 2015. As indicated above, we follow a number of recent studies (e.g., Hu and Png, 2012; Liu et al., 2021; Maskus and Yang, 2018), and use the effectively enforced patent rights protection "PRIE" in the analysis. The indicator "PRIE", which reflects the scope of effective patent rights protection, is computed by multiplying the index "PRI" by the index of legal enforcement (of contracts) effectiveness, the latter having been extracted from the Fraser Institute database.

Control variables "HUM", "POPGR", "GCONS" and "FDI" represent respectively the level of human capital (education) accumulated, the population growth rate, the share (in percentage) of government consumption in GDP, and the share of FDI inflows in GDP. Likewise, the variables "TERMS" and "INST" are respectively the indicators of terms of trade, and quality of institutions and governance. Data on the variables "POPGR", "GCONS", "FDI" "TERMS" and "INST" were extracted from the World Development Indicators (WDI) of the World Bank, while the indicator of human capital "HUM" was collected from the Penn World Tables 10.01 (see Feenstra et al., 2015), and represents the number of years of schooling and returns to education.

The control variable "INFL" is the transformed indicator of inflation rate denoted "INFLATION". The latter is the annual inflation rate (in percentage) based on consumer price index (in percentage) where missing values were replaced with values of the GDP Deflator (in percentage). Given its skewed distribution and the fact that it contains both positive and negative values, its transformation uses the following formula: $INFL = \text{sign}(INFLATION) * \log(1 + |INFLATION|)$ where $|INFLATION|$ refers to the absolute value of the annual inflation rate, denoted "INFLATION". The latter was extracted from the WDI of the World Bank.

The indicator of institutional and governance quality ("INST") was computed as the first principal component (using the factor analysis) of six indicators of governance indicators extracted

¹² This is the Organization for Economic Cooperation and Development/Donor Assistance Committee)-Credit Reporting System (CRS).

from World Bank Governance Indicators (see Kaufmann et al., 2010). These indicators are political stability and absence of violence/terrorism; regulatory quality; rule of law; government effectiveness; voice and accountability, and corruption. Higher values of the computed index indicate a better institutional and governance quality.

Appendix 1 provides a description and source of all variables contained in the model (1) as well as all other variables included later in the analysis. Appendices 2 and 3 report respectively the descriptive statistics over all variables used in the analysis, and the list of countries used in the analysis.

Data on the dependent variable "TFP" cover the sub-periods 2006-2010; 2011-2015 and 2016-2020, and data on the indicator "PRIE" is available over the years 2005; 2010 and 2015. Likewise, data on human capital covers the years 2005; 2010 and 2015. Data on all other variables cover the sub-periods 2002-2005; 2006-2010 and 2011-2015. This structure of the panel dataset (with the dependent variable and all regressors, covering 59 countries over the period from 2002 to 2019) allows mitigating severely the endogeneity problem, notably in the form of reverse causality from regressors to the dependent variable. Hence, as indicated above, the baseline model specification (1) allows uncovering the effect of AfT flows in the sub-period $t-1$ (for example the sub-period 2005-2009) on TFP in sub-period t (for example in the sub-period 2010-2014). This is consistent with the idea that it may take several years for development aid flows (including here AfT flows) to affect TFP (e.g., Groß and Danzinger, 2022). Nonetheless, we estimate here short-to-medium term effects of regressors, including AfT flows on the TFP level.

What are the expected effects of control variables? In contrast with our expectation of the positive effect of AfT flows on TFP level, NonAfT flows may not necessarily lead to an improvement in TFP, especially if these resources inflows do not favor the development of productive activities (for example when they are highly fungible) and encourage rent-seeking behaviour (e.g., Alvi and Senbeta, 2012; Economides et al., 2008; Groß and Danzinger, 2022). The negative effect of NonAfT flows on the TFP level can particularly materialize if these capital inflows lead to an appreciation of the real exchange rate (e.g., Gnanngnon, 2022) that would divert resource from the tradeable sector to the non-tradable sector. This would undermine the expansion of exportable industries (e.g., Rajan and Subramanian, 2011), which is a key engine of productivity improvement (e.g., Agénor, 2017).

A higher inflation rate is expected to reduce the TFP level by reducing efficiency and inducing a misallocation of resources (e.g., Edwards, 1998; Groß and Danzinger, 2017). A higher government spending may undermine productivity if it crowds-out private investment (e.g., Farla et al., 2016). It may foster productivity if it finances investment in areas where private investment is lacking (e.g., Groß and Danzinger, 2017). As a vector of transfer of technology to developing countries, FDI flows from developed countries could contribute to productivity improvement through their positive spillovers in the host countries (e.g., Borensztein et al. 1998). However, in the absence of such spillovers effects, it is unlikely that FDI inflows improve productivity in the host countries (e.g., Papyrakis and Gerlagh, 2004). By facilitating the absorption of the external knowledge, the accumulation of human capital can lead to a higher TFP level (e.g., Benhabib and Spiegel, 1994; Vandenbussche et al., 2006). However, the study by Miller and Upadhyay (2000) has revealed that the TFP growth effect of human capital depends on countries' level of economic development, as this effect was positive for middle-and high-income countries, and negative for

low-income countries. On another note, if the improvement in terms of trade makes the economy better off, and results in a higher investment in knowledge development activities and the expansion of tradables production, then it will lead to a higher TFP level (e.g., Teresiński, 2019). However, if it is associated with a lower investment in knowledge development activities at the benefit of merely the expansion of existing exported goods, then it can reduce the level of TFP. A positive effect of terms of trade on TFP has been uncovered by Bravo-Ortega and Marín (2011). An improvement in the quality of the political system (proxied by political institutions) can be associated with a higher TFP level (e.g., Sweet and Eterovic, 2019). Finally, the population growth rate can enhance productivity because of the positive effect of the labour force on productivity (e.g., Klasen and Nestmann, 2006).

3.2. Econometric approach

We commence the analysis by implementing the cluster-robust Hausman test proposed by Kaiser (2015) with a view to choosing among the fixed effects estimator and the random effects estimator, the one that is the most appropriate for estimating model (1). This test allows uncovering robust standard errors clustered at the country level, in contrast with the standard Hausman test of fixed effects estimator versus random effects estimator that has size distortions (see Kaiser, 2015). The outcomes of the cluster-robust Hausman test of Kaiser (2015) suggest a Chi-square statistic equal to 32.56, and the related p-value equal to 0.0002. These findings suggest that at the 1% level of statistical significance, the fixed effects estimator (henceforth denoted "FEDK") is more appropriate for estimating the baseline model (1) and all its different variants described below. In particular, we correct standard errors of the estimates by using the Driscoll and Kraay (1998) technique that accounts for the heteroscedasticity, serial correlation and contemporaneous cross-sectional dependence in the residuals. Summing-up, we estimate model (1) and its different variants described below using primarily the FEDK estimator.

The outcomes of the estimation of model (1) specifications where the variable "AfT" represents alternatively total AfT flows, and each of the component of the latter, are presented in Table 1. Note that we present in column [1] of this Table the outcomes of the specification of model (1) where the variable "PRIE" has been replaced with the indicator "PRI" which measures the 'rough' level of patent right protection, and not the effectively enforced one. The variable "PRIE" has been used in the specifications of model (1) whose results are presented in all other columns of Table 1. These outcomes help test hypothesis 1a (as part of hypothesis 1 set out in section 2) and hypothesis 3. Outcomes reported in Table 2 also help test hypothesis 1a by allowing to investigate the effect of AfT flows (both total AfT and its components) and patent rights protection on TFP in LDCs versus NonLDCs. These outcomes have been obtained by estimating different variants of model (1) that includes a dummy for LDCs (this dummy takes the value of 0 for LDCs¹³, and 1 for other developing countries), alongside the interaction variable between each AfT indicator (introduced once in the regressions) and the LDC dummy.

Estimates presented in Table 3 help test hypotheses 2, 4 and 5. In particular, outcomes in column [1] of Table 3 allow testing hypothesis 2. They have been obtained by estimating a specification of model (1) that is nothing else than model (1) in which we introduce the variable capturing trade costs, along with the interaction between this variable and the indicator of total

¹³ The full sample contains 15 LDCs. The list of these countries is provided in Appendix 3.

AfT flows. The indicator of overall trade costs ("TRCOST") was computed for a given country in a given year, as the average of the bilateral overall trade costs on goods across all trading partners of that country. Data on bilateral trade costs was extracted from the UNESCAP-World Bank Trade Cost Database that was built following the approach proposed by Novy (2013) (see Arvis et al. 2012, 2016). Arvis et al. (2012, 2016) have relied on the definition of trade costs by Anderson and van Wincoop (2004), and considered bilateral comprehensive trade costs as all costs involved in trading goods (agricultural and manufactured goods) internationally with another partner (i.e., bilaterally) relative to those involved in trading goods domestically (i.e., intranationally) (see Appendix 1 for further information on the computation of the indicator "TRCOST").

Estimates reported in column [2] of Table 3 are used to test hypothesis 4. They have been uncovered by estimating another specification of model (1) that includes an indicator of innovation output and the interaction between the latter and the indicator of total AfT flows. We use the economic complexity¹⁴ index to measure countries' innovative output, as it has the advantage of capturing both how countries have been able to achieve innovative outputs, and how they have integrated into their productive chain thanks *inter alia*, to incremental and leapfrog, tacit and codified knowledge (Sweet and Eterovic, 2019; Sweet and Maggio, 2015). These features of the economic complexity index are not captured by the indicator of the number of patent applications submitted (used as a measure of innovation output) as it focuses mainly on explicit knowledge embedded in goods produced and disregard the "tacit" knowledge accumulated in the goods produced (e.g., Nelson, 2005; Sweet and Maggio, 2015). The indicator of economic complexity ("ECI") is extracted from the Observatory of Economic Complexity of the Massachusetts Institute of Technology. Higher values of this index indicate a greater level of economic complexity.

Finally, results presented in column [3] of Table 3 are obtained from estimating a variant of model (1), which is model (1) in which we introduce the interaction variable between total AfT flows and the indicator "PRIE". These outcomes permit to test hypothesis 5.

Outcomes displayed in column [1] of Table 4 help test hypothesis 6 with the variable "AfT" being measured by total AfT flows. They have been obtained by estimating a specification of model (1) that includes not only the variable capturing R&D expenditure, but also four interaction variables: the interaction between the variables measuring total AfT flows, R&D expenditure, and the indicator "PRIE"; the interaction between the indicators of total AfT flows and "PRIE"; the interaction between the indicators of total AfT flows and R&D expenditure; and finally the interaction between the indicators of R&D expenditure and "PRIE". The indicator of R&D expenditure, denoted "RDCAP", is the real per capita R&D expenditure (constant 2015 US\$). Drawing from Bravo-Ortega and Marín (2011) who have established the strong exogeneity of the real per capita R&D expenditure to TFP, and shown its strong relevance for analyzing the effect of R&D expenditure on TFP, our indicator "RDCAP" has been calculated by multiplying the indicator of R&D intensity (i.e., the share of research and development expenditure in GDP - not expressed in percentage) by the real per capita GDP (constant 2015 US\$). Both the R&D intensity and the real per capita GDP were extracted from the WDI of the World Bank. R&D expenditure include both capital and current expenditures in four main sectors, including business enterprise,

¹⁴ Economic complexity reflects the diversity and ubiquity of a country's export structure, i.e., the diversification of the export product basket toward products with a low ubiquity (products with such unique features that there cannot be easily reproduced by other countries) (Hausmann and Hidalgo, 2009).

government, higher education, and private non-profit. R&D covers basic research, applied research, and experimental development (see the WDI of the World Bank).

4. Interpretation of estimations' outcomes

Results in column [1] of Table 1 show that both total AfT flows and the patent rights protection indicator "PRI" affect positively and significantly (at the 1% level) the productivity level. Likewise, estimates in column [2] of the same Table confirm the finding in column [1] concerning the positive and significant effect of total AfT flows on the TFP level (the coefficients of the variable "AfTTOT" are similar in the two columns). At the same time, a stronger level of the effective patent rights protection is associated with a higher TFP level, although the magnitude of the coefficient obtained here is almost half of the one associated with "PRI" in column [1] of the Table. These outcomes confirm hypothesis 1a. We obtain from column [2] of Table 1 that doubling the amount of total AfT (i.e., an increase in total AfT flows by 100%) is associated with an improvement in the level of TFP by 0.038 point. On the other side, a 1-point increase in the values of the index of effective protection of patent rights by 1 point is associated with an improvement in the level of TFP by 0.023 point.

Results in the other columns of the Table reveal that all components of total AfT flows affect positively and significantly (at the 1% level) the TFP level in developing countries. AfT flows for productive capacities appear to exert the largest positive effect on TFP, followed by AfT for economic infrastructure, and finally by AfT flows related to trade policy and regulation. Specifically, we observe that doubling AfT flows for economic infrastructure, AfT flows for productive capacities, and AfT flows for trade policy and regulation lead to an increase in the level of TFP respectively by 0.0214 point, 0.041 point, and 0.009 point.

Regarding control variables in all columns of Table 1, we find no significant effect (at the 10% level) of the population growth, the inflation rate, the government consumption, and inflows of FDI on the TFP level. While the institutional and governance quality appears to exert a positive and significant effect (at the 1% level) on TFP, the effect of NonAfT flows and terms of trade on TFP are negative and significant at least at the 5% level. The negative effect of NonAfT flows on TFP aligns, to some extent, with previous studies that have found a negative effect of development aid on TFP level. This finding may indicate that NonAfT flows do not encourage the expansion of productive activities, but rather rent-seeking behaviour (e.g., Alvi and Senbeta, 2012; Economides et al., 2008; Groß and Danzinger, 2022). The negative effect of terms of trade improvement on TFP may be explained by the fact that the revenues arising from the improvement terms of trade are not used (at the aggregate country level) to support the expansion of activities that contribute to the enhancement of TFP. On another note, the indicator of human capital affects negatively and significantly (at least at the 5% level) the TFP level. This puzzling result has also been obtained by Miller and Upadhyay (2000) who have concluded that the effect of human capital on TFP varies across levels of economic development.

It is important to note at this stage of the analysis that the outcomes of control variables in Tables 2 to 4 are broadly in line with those found in Table 1.

The estimations' results reported in column [1] of Table 2 show that AfT flows exert a higher positive effect on the TFP level in LDCs than in other developing countries. At the 5% level, the net effect of total AfT flows on the TFP level in LDCs amounts to 0.052 (= 0.0332 + 0.0188).

This indicates that doubling total AfT flows in LDCs results in an improvement in the TFP level by 0.052 point in these countries, while for NonLDCs (i.e., other developing countries), an increase in total AfT flows by 100 per cent induces an improvement in the TFP level by 0.033 point (see the coefficient of the variable "AfTTOT" in column [1] of Table 2). These outcomes reflect the fact that it is mostly AfT flows for productive capacities that explain the higher positive effect of total AfT flows on the TFP level in LDCs than in NonLDCs. This is because we observe in columns [2] to [4] of Table 2 that while AfT flows for economic infrastructure and AfT flows for trade policy and regulation affect equally the TFP level in LDCs and NonLDCs (the coefficients of the interaction variables in columns [2] and [4] are not significant at the 10% level), AfT flows for productive capacities exert a larger positive effect on the TFP level in LDCs than in NonLDCs. The net effect of AfT flows for productive capacities on the TFP level in LDCs and NonLDCs amounts respectively to 0.063 ($= 0.0297+0.0331$) and 0.033.

The finding that among three components of total AfT flows, AfT flows for productive capacities appear to be the only one that affects differently LDCs and NonLDCs is not really surprising. This is because on the one hand, AfT interventions for productive capacities target directly projects implemented to enhance the production of goods and services and hence firms' productivity in specific sectors. On the other hand, AfT interventions to strengthen economic infrastructure do not target specific sectors but affect the entire economy, thus benefit to all firms. They are, therefore, 'sector'-neutral (e.g., Cirera and Winters, 2015). Yet, as noted above, AfT interventions for trade policy and regulation can help facilitate trade, improve firms' productivity, and support least productive firms to sustain their activities and avoid closing down in the wake of trade liberalization reforms. However, the effect of this type of AfT interventions is unlikely to be as strong as that of AfT interventions for enhancement of productive capacities, since AfT for trade policy and regulation is the lowest share of total AfT flows compared to the two other components of total AfT flows (e.g., OECD/WTO, 2022).

We also note from column [1] of Table 1 that at the 5% level, the effective protection of patent rights exerts a higher positive effect on the TFP level in LDCs than in NonLDCs. Its net effects on the TFP level in LDCs and NonLDCs amount respectively to 0.083 ($= 0.0704 + 0.0126$) and 0.0126. This higher positive effect of the effective strengthening of patent rights on the TFP level in LDCs than in NonLDCs is quite surprising, but may be explained by the fact that despite the specific flexibilities available to them in the WTO's TRIPS Agreement, many LDCs have been strengthening their intellectual property laws (see the discussion in section 2). This may have affected their imitation levels and hence their TFP levels.

We now turn to results in Table 3. Outcomes in column [1] of this Table show that the coefficient of the interaction variable (" $[\text{Log}(\text{AfTTOT})]*[\text{Log}(\text{TRCOST})]$ ") is positive and significant at the 1% level, while the estimate related to the variable " $[\text{Log}(\text{AfTTOT})]$ " is negative and significant at the 1% level. Taken together, these two outcomes show that the effect of total AfT flows on the TFP level tends to increase as the overall trade costs rise, and change sign when the overall trade costs exceed 191 [$= \text{exponential}(0.428/0.0815)$]. As the values of the indicator "TRCOST" range from 189.1 to 460.9 (see Appendix 2), we can deduce that on average, over the full sample, total AfT flows lead to an increase in the TFP level in countries that face trade costs higher than the value of 191, and for these countries, the higher the trade costs (above the value of 191), the larger is the positive effect of total AfT flows on the TFP level. In the meantime, countries whose trade costs exceed the value of 191 experience a negative effect of total AfT flows

on TFP. Figure 1 provides, at the 95 per cent confidence intervals, the marginal impact of total AfT flows on the TFP level for different overall trade costs. It shows that this marginal impact increases as the trade costs rise. For low values¹⁵ of the overall trade costs (lower than 214, as per our calculation), there is no significant effect of total AfT flows on the TFP level. For values of the overall trade costs higher than 214, total AfT flows exert a positive and significant effect on the TFP level, and the greater the overall trade costs, the larger is the positive effect of total AfT flows on the TFP level. These findings lend support for hypothesis 1b.

Outcomes in column [2] of Table 3 show that the coefficients of both the variables "Log(AfTTOT)" and (" $[\text{Log}(\text{AfTTOT})] \cdot \text{ECI}$ ") are significant at the 1% level, with the former being positive, while the latter is negative. It ensues that, on average, over the full sample, total AfT flows exert a positive effect on the TFP level for values of the indicator of economic complexity lower than 0.67 ($= 0.0252/0.0375$). It is important to note here that the values of the indicator "ECI" range from -2 to 1.13 (see Appendix 2). Thus, countries whose values of ECI between -2 and 0.672 experience a positive effect of total AfT flows on the TFP level, while countries whose values of ECI exceed 0.67 experience a negative effect of total AfT flows on the TFP level. As these outcomes represent 'average effects' over the full sample, it could be useful to examine how total AfT flows affect the TFP level for different values of the indicator of economic complexity. Figure 2 shows, at the 95 per cent confidence intervals, the marginal impact of total AfT flows on the TFP level for varying degrees of economic complexity. It shows that this marginal impact decreases as the level of innovation output increases. In particular, for high levels of economic complexity (i.e., innovation output), there is at best no significant effect of total AfT flows on the TFP level (the effect can turn out to be negative for very high levels of economic complexity). However, for low values of innovation output, total AfT flows foster TFP, with the magnitude of this positive effect increasing as the level of innovation output decreases. In other words, total AfT flows exert a larger positive effect on the TFP level in low-income countries, including LDCs (as these countries have the lowest levels of innovation output) than in other developing countries. Overall, these findings support hypothesis 4.

We now consider the results in column [3] of Table 3. These results show patterns that are similar to those in column [2] of the same Table. In particular, we obtain that the coefficient of "Log(AfTTOT)" is positive and significant at the 1% level, while the interaction term of the variable (" $[\text{Log}(\text{AfTTOT})] \cdot \text{PRIE}$ ") is negative and significant at the 1% level. It follows that total AfT flows exert a positive effect on the TFP level for values of the indicator "PRIE" lower than 2.533 ($= 0.0737/0.0291$). The values of this indicator in the full sample range from 0 to 2.655. As a consequence, on average over the full sample, total AfT flows exert a positive effect on the TFP level in countries whose levels of PRIE are lower than 2.533 (i.e., comprised between 2.533 and 2.655). For these countries, the lower the levels of PRIE (than 2.533), the larger is the magnitude of the positive effect of total AfT flows on the TFP level. This signifies that on average over the full sample, total AfT flows exert a larger positive effect on the TFP level in countries that implement weak effective patent rights protection, and the weaker the level of patent rights protection, the higher is the positive effect of total AfT flows on the TFP level. These findings are confirmed by Figure 3 which displays, at the 95 per cent confidence intervals, the marginal impact

¹⁵ We obtain from this graph that this level of trade costs below which total AfT flows exert no significant effect on the TFP level amounts to 214.

of total AfT flows on the TFP level for different levels of the effective patent rights protection. It appears that this marginal impact is almost always positive, but decreases as the values of the indicator "PRIE" increase. It is statistically nil for very high levels of PRIE (i.e., values higher than 2.284 - obtained when constructing the graph in Figure 3), that is, in countries that have the strongest levels of PRIE. Put differently, except in countries with very high levels of PRIE where its effect is statistically nil, total AfT always induces a positive effect on the TFP level, and the magnitude of this positive effect is higher, the lower the level of PRIE. These findings support hypothesis 5, and are consistent with the interpretation we made concerning results in column [2] of Table 3. In fact, countries with low levels of innovation output (i.e., here, economic complexity) are those that have weak levels of PRIE. Given that we found a larger positive effect of total AfT flows on the TFP level in countries that have lower levels of innovation output, it is not surprising that the positive effect of total AfT flows on TFP is larger in countries with the weaker PRIE levels.

Finally, we consider outcomes presented in column [1] of Table 4 that help test hypothesis 6. To recall, we are interested here in how total AfT flows affect the level of TFP in countries that experience an increase in both the real per capita R&D expenditure and the level of effective patent rights protection. Thus, among variables whose results are reported in Table 4, we are interested in the coefficients of two interaction variables, namely the interaction variables "[Log(AfT)]*PRIE*RDCAP" and "PRIE*RDCAP". The coefficient of the former is positive and significant at the 5% level, while the coefficient of the latter is negative and significant at the 5% level. Figure 4 provides, at the 95 per cent confidence intervals, the marginal impact of total AfT flows on the TFP level for different values of the interaction variable "PRIE*RDCAP". It appears from Figure 4 that this marginal impact is always positive and significant, and increases as the values of the combined PRIE and R&D expenditure increase. In other words, countries that increase R&D expenditure and effectively strengthen their patent rights protection enjoy a higher positive effect of total AfT flows on the TFP level. The higher the values of the interaction variable "PRIE*RDCAP", the larger is the magnitude of the positive effect of total AfT flows on the TFP level.

In view of the importance of AfT interventions for productive capacities to foster TFP in developing countries (see our interpretation of results in Table 2), we find useful to re-estimate the specification of model (1) whose results were reported in column [1] of Table 4, by using AfT flows for productive capacities rather than total AfT flows as measure of the variable "AfT". The results of this estimation are presented in column [2] of Table 4. The objective of carrying out the estimation of this new variant of model (1) is to investigate how AfT interventions for productive capacities affect the TFP level in countries that experience both an increase in the real per capita R&D expenditure and the strengthening of their patent rights protection. We find from column [2] of Table 4 that the patterns of results therein are similar to the ones obtained when the variable "AfT" was measured by total AfT flows (see results in column [1] of Table 4). Figure 5 shows at the 95 per cent confidence intervals, the marginal impact of AfT flows for productive capacities on the TFP level for different values of the interaction variable "PRIE*RDCAP". Like in Figure 4, this marginal impact is always positive and significant, and additionally increases as the values of the combined R&D expenditure and PRIE indicators increase.

Summing-up, the analysis has shown that total AfT interventions, including AfT interventions for economic infrastructure, AfT interventions for productive capacities, and AfT

interventions related to trade policy and regulation exert a positive effect on the level of TFP. The largest positive TFP effect is obtained for AfT interventions for productive capacities, followed by AfT interventions for economic infrastructure, and finally, AfT interventions related to trade policy and regulation. Moreover, total AfT flows exert a larger positive effect on the TFP level in countries with higher trade costs, lower levels of innovation output, and weaker effective protection of patent rights. It also appears that total AfT flows and AfT flows for productive capacities affect positively the TFP level in countries that increase both their real per capita R&D expenditure and the level of their effective patent rights protection level. The greater the combined level of R&D expenditure and PRIE, the larger is the positive effect of total AfT flows and AfT interventions for productive capacities on the TFP level.

5. Further analysis

The estimates arising from using the FEDK estimator represent 'average' effects of regressors, including AfT indicators over the full sample. In other words, for each regressor, the estimate obtained is nothing else than its effect on the TFP level at the mean of the conditional distribution of TFP. It can be useful from an empirical perspective, to examine how regressors, notably our two variables of interest, affect different quantiles of the TFP distribution. To do so, we make use of the panel quantile regression approach, especially the Method of Moments Quantile Regression (MMQR) with fixed effects approach (also known as "Quantile via Moments") developed by Machado and Santos Silva (2019). Like standard quantile regression approaches (e.g., Canay, 2011; Koenker, 2004), the MMQR technique addresses the heteroscedasticity and outliers problems. However, the MMQR has many positive features that other panel quantiles do not have. In other panel quantiles approaches (e.g., those that rely on the ordinary least squares fixed effects estimator), countries' time-invariant fixed effects represent location (intercept) shifters (e.g., Heckman et al., 1997), while in the MMQR approach, countries' fixed effects vary across different quantiles of the conditional distribution of the dependent variable. More importantly, by using the method of moments, the MMQR approach helps overcome the endogeneity problems (i.e., the endogeneity of regressors) in the model estimated. In the present analysis, even though the structure of the panel dataset used to estimate model (1) (and its different variants described below) limits the endogeneity concern that may arise from the reverse causality problem, the MMQR approach definitely settles these endogeneity problems.

Three conditional quantiles for TFP are obtained by means of the following panel quantile function:

$Q_{TFP_{it}}(\tau/X_{it}) = [(\mu_i + \delta_i q(\tau)) + X_{it}\beta + Z_{it}\gamma q(\tau)]$ (2), where the scalar parameter $\mu_i(\tau) = \mu_i + \delta_i q(\tau)$ indicates the quantile- τ fixed effects for individual country i , or the distributional effect at τ . It captures the time-invariant effect of individual country characteristics that potentially vary depending on where a country is located in the conditional distribution of TFP.

From equation (2), the conditional quantile function of TFP $q(\tau)$ (i.e., the τ -th quantile) based on the MMQR approach, is obtained by optimizing the following function:

$\min_q \sum_i \sum_t \theta_\tau(\hat{R}_{it} - (\hat{R}_{it} + Z'_{it} \hat{\gamma})q)$ (3), where the check function $\theta_\tau(A) = (\tau - 1)AI\{A \leq 0\} + \tau AI\{A > 0\}$ is the standard quantile loss function.

In the present work, the MMQR approach is used to examine empirically the effect of the AfT flows on the level of TFP across the distribution of TFP, for 5 quantiles, including Q10th (i.e., the 10th quantile), Q25th, Q50th, Q75th and Q90th (i.e., the 90th quantile).

We use the MMQR approach to estimate specifications of model (1) with the different indicators of AfT flows (total AfT flows and each of its components). Table 5 contains the outcomes of the estimation of model (1) where the variable "AfT" is measured by total AfT flows. Table 6¹⁶ presents the results of the estimation of specifications of model (1) where the variable "AfT" is measured by each component of total AfT. We provide in Table 7¹⁷, the summary of the estimations' outcomes of the specifications of model (1) (which are the most ones of interest in the analysis) that allow testing hypotheses 5 and 6. For the sake of brevity and to save space, we have reported the outcomes of these estimations obtained over only the key variables of interest in the analysis as well as the variable capturing NonAfT flows. We choose to report the estimates of the latter because of both NonAfT flows and AfT flows form total ODA flows.

We now turn to outcomes obtained from the use of the MMQR approach (see results in Tables 5 to 7). Results in Table 5 show that the location parameter relating to the variable "Log(AfT/TOT)" is positive and significant at the 1% level, while the scale parameter associated with the same variable is yet positive, but not significant at the 10% level. It ensues that the effect of total AfT flows on the level of TFP is yet positive, but its scale diminishes as we move from lower quantiles to upper ones. Specifically, we observe that total AfT flows affect positively the TFP level in all quantiles of the distribution of TFP, and the magnitude of this positive effect is larger in lower quantiles of the distribution of TFP than in the upper quantiles. The magnitude of this effect ranges from 0.027 for the 10th quantile to 0.039 for the 90th quantile. Thus, countries with low levels of TFP benefit from a larger positive effect of total AfT flows on the TFP level than countries that enjoy higher levels of TFP.

We also note from Table 5 that the effective implementation of patent rights protection exerts no significant effect (at the conventional levels) on the TFP level across all quantiles of the distribution of TFP.

We obtain that NonAfT flows reduce the TFP level across all quantiles, with the magnitude of this negative effect being higher in upper quantiles than in relatively lower quantiles. The improvement in terms of trade affects negatively TFP in all quantiles (at least the 10% level) with this effect being larger in lower quantiles than in upper quantiles. This suggests that the improvement in terms of trade is more detrimental to TFP in countries with low levels of TFP than in those with relatively higher levels of TFP. An increase in the population growth rate influences positively and significantly (at the 5% level) only countries located in the 10th quantile of the distribution of TFP (i.e., countries that have the lowest level of TFP) as for countries situated in the other quantiles, the effect of this variable is statistically nil at the conventional significance levels. The inflation rate indicator affects only significantly (and only at the 10% level) the TFP level in countries with the lowest levels of TFP (i.e., those located in the 10th quantile). For all other quantiles, there is no significant effect of inflation on TFP. The improvement in the institutional and governance quality exerts a positive and significant effect (only at the 10% level) on the TFP

¹⁶ The full estimations' results could be obtained upon request.

¹⁷ The full estimations' results could be obtained upon request.

level for countries located in upper quantiles, that is, the 75th and 90th quantiles of the TFP distribution. Its effect is larger for countries in the 90th quantile than for those in the 75th quantile. For all other quantiles, it exerts no significant effect on TFP. Incidentally, there is no significant effect of government consumption and FDI inflows on TFP across all quantiles of the TFP distribution.

Turning to estimates reported in Table 6, we observe no significant effect of AfT interventions for trade policy and regulation on TFP across all quantiles of the TFP distribution. However, at the 5% level, AfT interventions for economic infrastructure lead to a greater TFP level in countries located in the 25th to 90th quantiles, with the magnitude of this positive effect being larger for countries in upper quantiles than for those in relatively lower quantiles. In other words, AfT interventions for economic infrastructure lead to a higher productivity improvement in countries with higher TFP levels than in those with relatively lower TFP levels. AfT flows for economic infrastructure affect positively TFP (but only at the 10% level) for countries with the lowest TFP levels (i.e., those situated in 10th quantile). The magnitude of the positive effect of AfT interventions for economic infrastructure on the TFP level range from 0.013 (for the 10th quantile) to 0.024 (for the 90th quantile).

The effect of AfT interventions for productive capacities on the TFP level is larger than the one observed for the AfT interventions for economic infrastructure, especially for countries located in the 50th to 90th quantiles, when considering the significance of estimates at the 5% level. At the 5% level, AfT flows for strengthening productive capacities exert a larger positive effect on the TFP level for countries situated in the 50th to 90th quantiles. The magnitude of this effect range from 0.031 for countries in the 50th quantile to 0.043 in the 90th quantile. For countries in the 10th quantile, there is no significant effect of AfT flows for productive capacities on the TFP level, while this effect is yet positive but significant only at the 10% level for countries situated in the 25th quantile.

The strengthening of patent rights protection exerts no significant effect on the TFP level across all quantiles of the TFP distribution. NonAfT flows tend to exert a negative effect on the TFP level, with the effect of these resource inflows on TFP being larger for countries situated in the upper quantiles than for those located in relatively lower quantiles. Note, however, that for regressions where the variable "AfT" is measured by AfT flows related to trade policy and regulation, there is almost no significant effect of NonAfT flows on TFP across quantile. It is worth noting here that the outcomes concerning the control variables in Table 6 are quite similar to those observed in Table 5. As noted above, these outcomes could be obtained upon request.

Outcomes in the upper part of Table 7 show that across all quantiles, total AfT flows affect positively and significantly the TFP level, with the magnitude of this positive effect being larger for countries located in upper quantiles than those situated in the lower quantiles. In the meantime, the effective implementation of patent rights protection also leads to an improvement of TFP, with the magnitude of this positive effect be larger in countries that have higher levels of TFP (i.e., those located in the upper quantiles) than in those with lower TFP levels. Interestingly, and more importantly, the interaction term of the variable "[Log(AfT/TOT)]*PRIE" is negative and significant at the 10% level for countries in the lowest quantile (10th quantile), but negative and significant at the 5% level in other quantiles. The coefficient associated with this interaction variable diminishes in absolute value as we move from the lowest quantile to the highest quantile. This signifies that total AfT flows exert a larger positive effect on TFP in countries that have low

TFP levels than in countries with high TFP levels when countries implement effectively weak protection of patent rights.

Outcomes reported in the middle of Table 7 indicate that at the 1% level, total AfT flows affect positively and significantly the TFP level in countries situated in the lower quantiles (especially in the 10th to 50th quantiles) that increase R&D expenditure and concurrently strengthen their patent rights protection. Specifically, this effect is larger in countries located in the lowest quantile (e.g., the 10th quantile) than in those located in upper quantiles (up to the 50th quantile). Interpreted differently, this finding shows that countries that have low TFP levels and that endeavour to increase their real per capita R&D expenditure while concurrently strengthening their patent rights to protect the returns on the R&D investment, enjoy a higher positive effect of total AfT flows on the TFP level. On another note, total AfT flows exert no significant effect on TFP for countries situated in the upper quantile (i.e., 90th quantile) that both increase their R&D expenditure and strengthen their patent rights. However, the effect of these resources inflows is positive but significant only at the 10% level for countries in the 75th quantile that increase R&D expenditure and simultaneously strengthen their patent rights.

These outcomes in the middle part of Table 7 are confirmed by those at the lower part of Table 7 concerning the effect of AfT flows for productive capacities on the TFP level when countries increase their R&D expenditure and concurrently adopt stronger patent laws. We observe that this effect is not statistically significant at the conventional significance levels for countries in the 50th to 90th quantiles of the TFP distribution. In contrast, it is positive and significant for countries situated in lower quantiles, i.e., in the 10th and 25th quantiles, with its magnitude being larger for countries that have the lowest TFP levels (i.e., those in the 10th quantile) than for countries with relatively higher TFP levels (i.e., those in the 25th quantile).

6. Conclusion

The present study connects two strands of the literature on the determinants of the TFP level, namely the literature on the TFP effect of development aid, and the literature on the effect of IPR protection (in particular patent rights protection) on the TFP level. It investigates the effect of AfT flows on the TFP level and whether this effect depends on the strength of IPR protection. To that end, it has used a panel dataset of 59 countries over the period from 2002 to 2019 and relied on the within fixed effects estimator and the Method of Moments Quantile Regression approach. The findings indicate that AfT interventions (including both total AfT and each of its three main components) are instrumental in improving the TFP level in recipient countries. AfT flows for productive capacities appear to exert the largest effect on the TFP level, followed by AfT interventions for economic infrastructure, and AfT interventions for trade policy and regulations. In particular, the positive productivity effect of total AfT flows is larger in countries with higher productivity levels. On average, LDCs experience a higher positive effect of total AfT flows (including AfT for productive capacities) and a larger positive effect of patent rights protection on the TFP level. Additionally, total AfT flows exert a larger positive effect on the TFP level in countries that face higher trade costs, lower innovative output and weaker patent rights protection. Likewise, a higher R&D expenditure coupled with stronger patent rights laws (to protect the returns on these R&D expenditure) lead to a larger positive effect of total AfT flows on the TFP level. This finding applies particularly to countries that have low levels of TFP.

The findings of this analysis shed light on the potential for AfT flows to help improve productivity, including in countries that increase their innovation effort through, *inter alia*, higher R&D expenditure while concurrently strengthening patent rights laws to protect innovators' returns on these expenditure. The analysis shows that while AfT flows can be effective in improving the aggregate productivity in recipient countries that have weak patent rights protection, those countries that increase R&D expenditure to enhance firms' absorptive capacity of foreign knowledge and processes need to adopt stronger patent rights laws. The strength of IPR protection to ensure this positive effect of AfT flows on productivity is likely to depend on each country's characteristics and development strategies. It is also worth noting that the effective implementation of stronger patent rights laws does not affect uniformly all firms. In developing countries that have weak IPR policy, firms that endeavour to increase their innovation effort, including through a higher R&D expenditure, can use a variety of internal organizational mechanisms to offset the absence of stronger intellectual property laws (e.g., Faria and Sofka, 2010; Zhao, 2006). For example, Zhao (2006) has found that in countries with weak IPR protection, technologies developed by firms tend to be used internally, and specifically, those developed by firms with R&D show stronger internal linkages. In this context, as strengthening IPR protection in LDCs might not be an option to ensure that AfT flows help improve productivity when R&D expenditure increases, LDC governments may consider supporting firms' innovation effort to rely on internal organizations as a substitute for inadequate external institutions.

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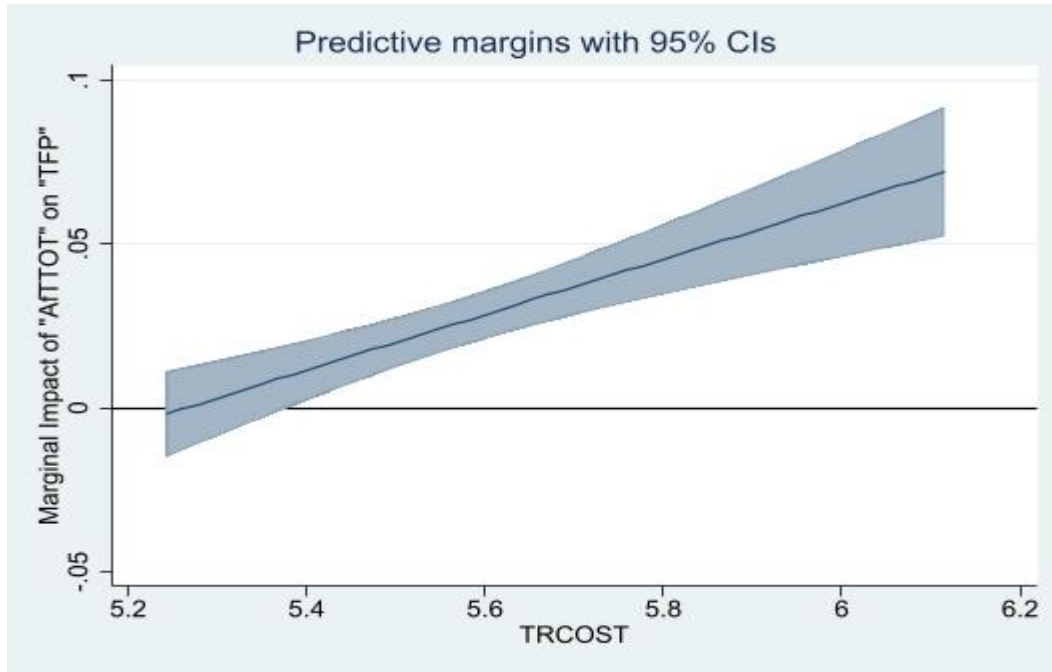
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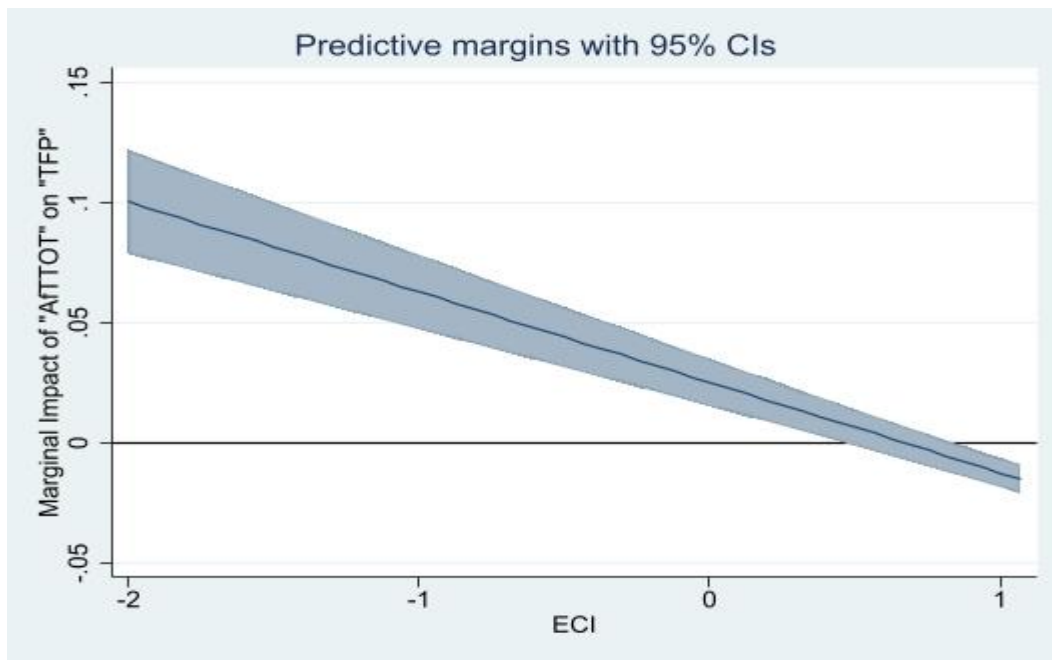
FIGURES

Figure 1: Marginal Impact of "AFTTOT" on "TFP" for varying levels of trade costs_Over the full sample



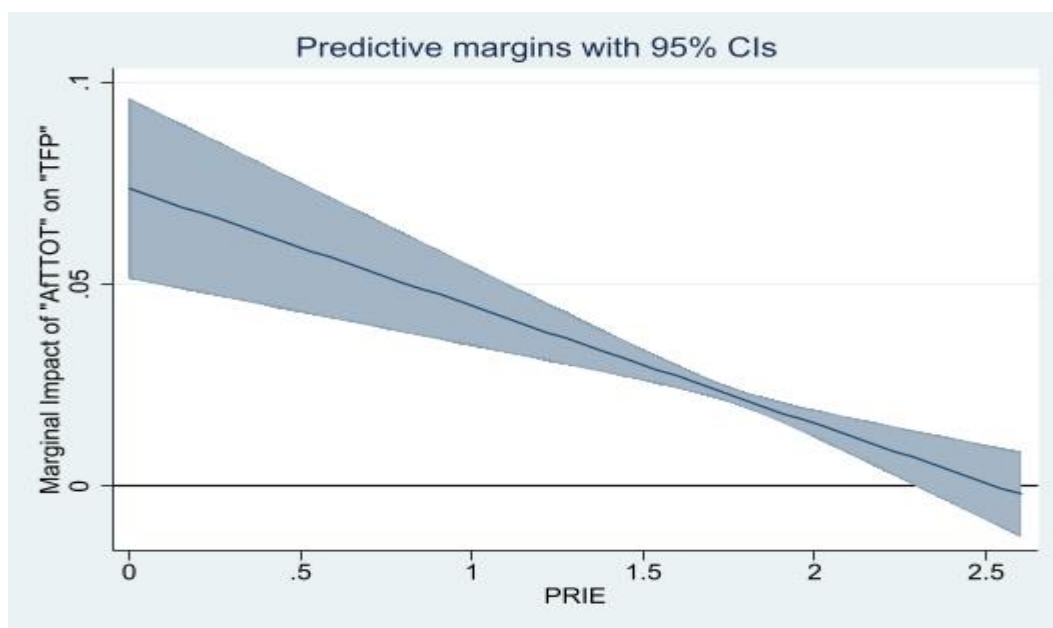
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Figure 2: Marginal Impact of "AFTTOT" on "TFP" for varying levels of Innovation output (Economic Complexity)_Over the full sample



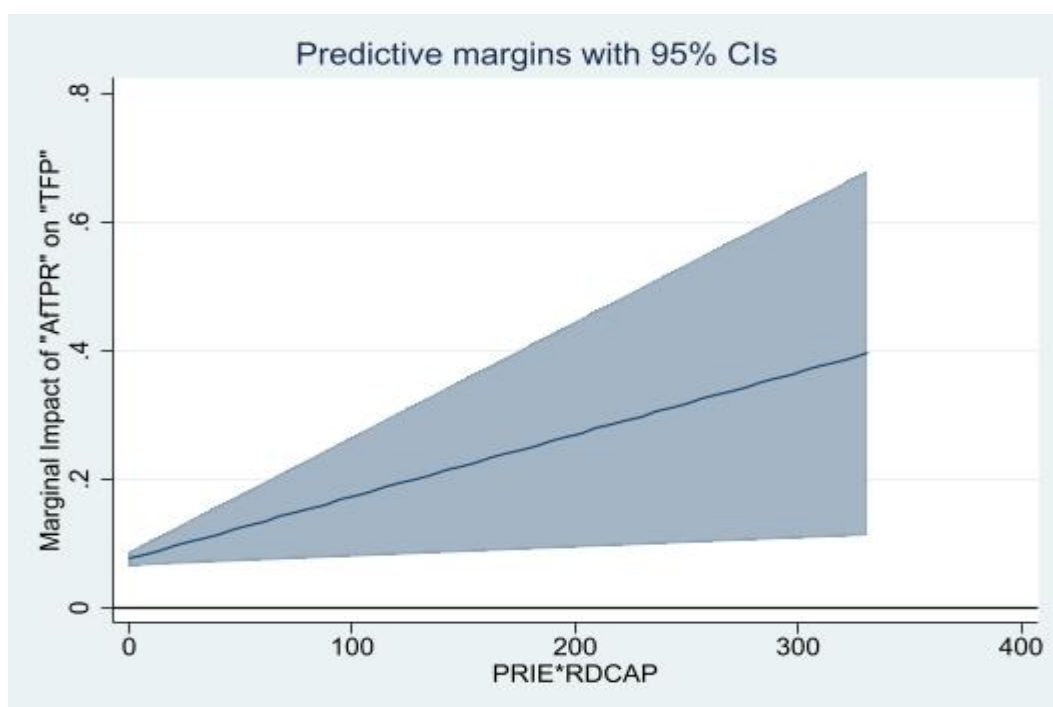
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Figure 3: Marginal Impact of "AfITOT" on "TFP" for varying levels of PRIE_Over the full sample



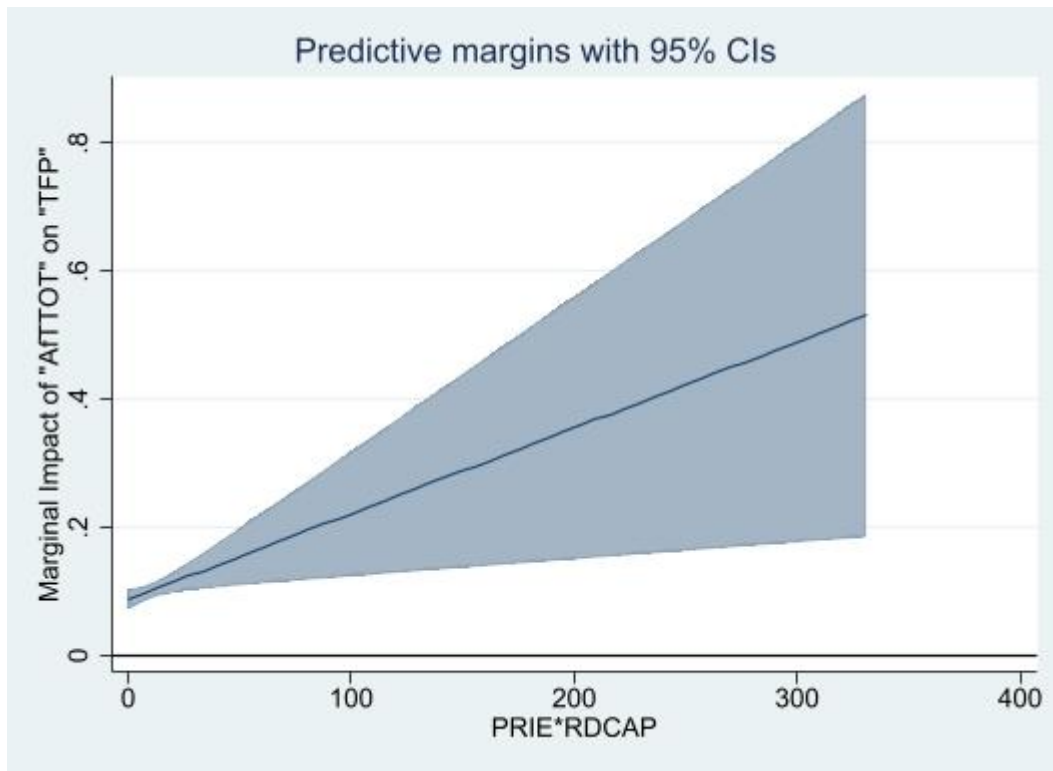
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Figure 4: Marginal Impact of "AfTPR" on "TFP" for varying levels of the combined levels of PRIE and the real per capita R&D expenditure_Over the full sample



Source: Author

Figure 5: Marginal Impact of "AfTTOT" on "TFP" for varying levels of the combined levels of PRIE and the real per capita R&D expenditure_Over the full sample



Source: Author

TABLES and APPENDICES

Table 1: Effect of the total AfT flows and PRI on the TFP level_Over the full sample
Estimator: FEDK

Variables	TFP (1)	TFP (2)	TFP (3)	TFP (4)	TFP (5)
Log(AfT*TOT)	0.0369*** (0.00364)	0.0383*** (0.00382)			
PRI	0.0433*** (0.0107)				
PRIE		0.0230*** (0.00833)	-0.000293 (0.00790)	0.0496*** (0.0104)	0.0335*** (0.0112)
Log(AfTINF)			0.0214*** (0.00269)		
Log(AfTIPR)				0.0406*** (0.00445)	
Log(AfTPOL)					0.00858*** (0.00260)
Log(NonAfT)	-0.0403*** (0.00880)	-0.0418*** (0.00988)	-0.0325*** (0.0105)	-0.0418*** (0.00916)	-0.0202*** (0.00672)
HUM	-0.148*** (0.0355)	-0.106*** (0.0324)	-0.0893*** (0.0331)	-0.0526** (0.0201)	0.00847 (0.0352)
POPGR	0.00625 (0.00579)	0.00653 (0.00587)	0.00829 (0.00575)	0.00814 (0.00818)	0.00909 (0.00670)
INFL	-0.00196 (0.00601)	-0.00295 (0.00595)	-0.00631 (0.00631)	-0.00319 (0.00617)	-0.000710 (0.00405)
GCONS	-0.00355 (0.00255)	-0.00366 (0.00255)	-0.00338 (0.00246)	-0.00396 (0.00270)	-0.00251 (0.00306)
FDI	-0.00180* (0.00105)	-0.00171* (0.000979)	-0.00151 (0.000938)	-0.00136 (0.000962)	-0.000683 (0.00116)
TERMS	-0.000452** (0.000216)	-0.000483** (0.000220)	-0.000436** (0.000212)	-0.000613*** (0.000212)	-0.000572*** (0.000206)
INST	0.0160*** (0.00282)	0.0195*** (0.00335)	0.0209*** (0.00405)	0.0241*** (0.00424)	0.0195*** (0.00654)
Constant	0.995*** (0.0885)	1.024*** (0.116)	1.157*** (0.134)	0.890*** (0.0733)	0.904*** (0.0797)
Observations - Countries	173 - 59	173 - 59	173 - 59	173 - 59	171 - 59
Within R ²	0.2169	0.1990	0.1837	0.1756	0.1199

Note: **p*-value<0.1; ***p*-value<0.05; ****p*-value<0.01. Robust standard errors are in parenthesis.

Table 2: Effect of the total AfT flows and PRI on the TFP level in LDCs versus NonLDCs
Estimator. FEDK

Variables	TFP (1)	TFP (2)	TFP (3)	TFP (4)
Log(AfTTOT)	0.0332*** (0.00182)			
[Log(AfTTOT)]*LDC	0.0188** (0.00931)			
PRIE	0.0126** (0.00591)	-0.000375 (0.00845)	0.0436*** (0.00814)	0.0394*** (0.0116)
PRIE*LDC	0.0704** (0.0314)			
[Log(AfTINF)]*LDC		0.0108 (0.00826)		
Log(AfTINF)		0.0184*** (0.00156)		
[Log(AfTPR)]*LDC			0.0297** (0.0134)	
Log(AfTPR)			0.0331*** (0.00346)	
[Log(AfTPOL)]*LDC				-0.00667 (0.00514)
Log(AfTPOL)				0.0113*** (0.00333)
Log(NonAfT)	-0.0455*** (0.0113)	-0.0337*** (0.0112)	-0.0426*** (0.0103)	-0.0183** (0.00772)
HUM	-0.0811*** (0.0287)	-0.0703** (0.0283)	-0.0276 (0.0221)	0.00291 (0.0364)
POPGR	0.00577 (0.00605)	0.00851 (0.00595)	0.00663 (0.00829)	0.00883 (0.00675)
INFL	-0.00357 (0.00627)	-0.00673 (0.00640)	-0.00519 (0.00741)	-0.000341 (0.00416)
GCONS	-0.00377 (0.00229)	-0.00370* (0.00215)	-0.00464* (0.00243)	-0.00276 (0.00295)
FDI	-0.00172 (0.00111)	-0.00147 (0.000960)	-0.00144 (0.00109)	-0.000817 (0.00107)
TERMS	-0.000608** (0.000278)	-0.000514* (0.000266)	-0.000711*** (0.000250)	-0.000540*** (0.000201)
INST	0.0185*** (0.00364)	0.0218*** (0.00430)	0.0185** (0.00702)	0.0196*** (0.00638)
Constant	1.066*** (0.148)	1.159*** (0.150)	0.877*** (0.109)	0.854*** (0.111)
Observations - Countries	173 - 59	173 - 59	173 - 59	171 - 59
Within R ²	0.2092	0.1890	0.1864	0.1242

Note: *p-value<0.1; **p-value<0.05; ***p-value<0.01. Robust standard errors are in parenthesis.

Table 3: Effect of the total AfT flows on the TFP level for varying levels of trade costs, innovation output, and intellectual protection
Estimator. FEDK

Variables	TFP (1)	TFP (2)	TFP (3)
Log(AfT ^{TOT})	-0.428*** (0.0979)	0.0252*** (0.00503)	0.0737*** (0.0114)
[Log(AfT ^{TOT})]*[Log(TRCOST)]	0.0815*** (0.0175)		
[Log(AfT ^{TOT})]*ECI		-0.0375*** (0.00328)	
[Log(AfT ^{TOT})]*PRIE			-0.0291*** (0.00642)
Log(TRCOST)	-1.346*** (0.365)		
ECI		0.655*** (0.0802)	
PRIE	0.0179 (0.0134)	0.0249*** (0.00703)	0.551*** (0.128)
Log(NonAfT)	-0.0456*** (0.00622)	-0.0433*** (0.0114)	-0.0430*** (0.0113)
HUM	-0.0668* (0.0354)	0.0148 (0.0790)	-0.0769** (0.0378)
POPGR	0.00706** (0.00324)	0.00977*** (0.00288)	0.00558 (0.00585)
INFL	-0.00325 (0.00494)	0.0120 (0.00824)	-0.00321 (0.00567)
GCONS	-0.00444 (0.00280)	-0.00440 (0.00300)	-0.00493** (0.00220)
FDI	-0.00137 (0.00114)	-0.00352** (0.00159)	-0.00184* (0.00104)
TERMS	-0.000587** (0.000236)	-0.000977*** (0.000235)	-0.000473** (0.000209)
INST	0.00718 (0.00480)	0.0358** (0.0168)	0.0124** (0.00515)
Constant	8.741*** (2.131)	1.086*** (0.108)	0.361 (0.250)
Observations - Countries	170 - 58	143 - 53	173 - 59
Within R ²	0.2546	0.3207	0.2284

Note: *p-value<0.1; **p-value<0.05; ***p-value<0.01. Robust standard errors are in parenthesis.

Table 5: Interaction effect of total AfT flows (and alternatively AfT for productive capacities) with PRI and the per capita R&D expenditure level on the TFP level_Over the full sample
Estimator. FEDK

Variables	TFP (1)	TFP (2)
	AfT = AfTTOT	AfT = AfTPR
[Log(AfT)]*PRIE*RDCAP	0.00134** (0.000550)	0.000967** (0.000420)
[Log(AfT)]*PRIE	-0.0432*** (0.00595)	-0.0315*** (0.000795)
[Log(AfT)]*RDCAP	-0.00255** (0.000975)	-0.00197** (0.000769)
PRIE*RDCAP	-0.0271** (0.0104)	-0.0191** (0.00748)
Log(AfT)	0.0875*** (0.00800)	0.0762*** (0.00579)
PRIE	0.872*** (0.102)	0.634*** (0.0436)
RDCAP	0.0514*** (0.0184)	0.0388*** (0.0135)
Log(NonAfT)	-0.0196 (0.0145)	-0.0210* (0.0110)
HUM	0.0215** (0.00963)	-0.00429 (0.0287)
POPGR	-0.0253*** (0.000699)	-0.0248*** (0.00214)
INFL	0.0361*** (0.00640)	0.0390*** (0.00752)
GCONS	-0.00186 (0.00208)	-0.00127 (0.00220)
FDI	-0.00373*** (0.00136)	-0.00335** (0.00156)
TERMS	-0.000806*** (0.000111)	-0.000728*** (0.000103)
INST	0.0121*** (0.00200)	0.0262*** (0.00881)
Constant	-0.655** (0.248)	-0.318 (0.281)
Observations - Countries	110 - 46	110 - 46
Within R ²	0.3044	0.2602

Note: *p-value<0.1; **p-value<0.05; ***p-value<0.01. Robust standard errors are in parenthesis.

Table 5: Effect of total AfT flows on the TFP level_Over the full sample
Estimator. Method of Moments Quantile Regression (MMQR)

Variables	Location ^a (1)	Scale ^b (2)	Q10 th (3)	Q25 th (4)	Q50 th (5)	Q75 th (6)	Q90 th (7)
Log(AfT/TOT)	0.0331*** (0.0110)	0.00403 (0.00345)	0.0269** (0.0127)	0.0291** (0.0118)	0.0330*** (0.0110)	0.0375*** (0.0113)	0.0389*** (0.0115)
PRIE	0.0127 (0.0365)	0.00983 (0.0106)	-0.00239 (0.0460)	0.00308 (0.0419)	0.0124 (0.0367)	0.0233 (0.0334)	0.0268 (0.0332)
Log(NonAfT)	-0.0479*** (0.0139)	-0.00448 (0.00494)	-0.0410*** (0.0156)	-0.0435*** (0.0145)	-0.0477*** (0.0139)	-0.0527*** (0.0151)	-0.0543*** (0.0158)
HUM	-0.131 (0.102)	0.00635 (0.0346)	-0.140 (0.123)	-0.137 (0.113)	-0.131 (0.102)	-0.124 (0.101)	-0.121 (0.104)
POPGR	0.00751 (0.0131)	-0.00954** (0.00425)	0.0222** (0.00994)	0.0168 (0.0108)	0.00782 (0.0132)	-0.00283 (0.0166)	-0.00614 (0.0175)
INFL	-0.0101 (0.0160)	0.0108** (0.00426)	-0.0267* (0.0161)	-0.0207 (0.0160)	-0.0105 (0.0162)	0.00155 (0.0174)	0.00529 (0.0178)
GCONS	-0.00296 (0.00228)	0.000304 (0.000806)	-0.00343 (0.00281)	-0.00326 (0.00256)	-0.00297 (0.00228)	-0.00263 (0.00226)	-0.00252 (0.00232)
FDI	-0.00219 (0.00179)	-0.000793* (0.000470)	-0.000977 (0.00161)	-0.00142 (0.00163)	-0.00217 (0.00179)	-0.00305 (0.00207)	-0.00333 (0.00215)
TERMS	-0.000635** (0.000276)	0.000191* (9.75e-05)	-0.000928** (0.000377)	-0.000822** (0.000346)	-0.000642** (0.000282)	-0.000429* (0.000227)	-0.000362* (0.000213)
INST	0.0181 (0.0136)	0.00460 (0.00477)	0.0110 (0.0163)	0.0136 (0.0151)	0.0179 (0.0137)	0.0231* (0.0138)	0.0247* (0.0142)
Constant	1.329*** (0.332)	0.000350 (0.119)	1.328*** (0.374)	1.328*** (0.349)	1.329*** (0.332)	1.329*** (0.359)	1.329*** (0.377)
Observations	173	173	173	173	173	173	173

Note: **p*-value<0.1; ***p*-value<0.05; ****p*-value<0.01. Robust standard errors are in parenthesis. (a) indicates the location parameters, and (b) refers to the scale parameters.

Table 6: Effect of the components of total AfT flows on the TFP level_Over the full sample
Estimator. Method of Moments Quantile Regression (MMQR)

Variables	Location ^a (1)	Scale ^b (2)	Q10 th (3)	Q25 th (4)	Q50 th (5)	Q75 th (6)	Q90 th (7)
Results of the effect of AfT flows for economic infrastructure on TFP							
Log(AfTINF)	0.0185*** (0.00593)	0.00367* (0.00192)	0.0128* (0.00661)	0.0148** (0.00614)	0.0181*** (0.00598)	0.0224*** (0.00639)	0.0240*** (0.00663)
PRIE	-0.00899 (0.0353)	0.00564 (0.0100)	-0.0177 (0.0431)	-0.0147 (0.0399)	-0.00966 (0.0357)	-0.00300 (0.0332)	-0.000554 (0.0334)
Log(NonAfT)	-0.0406*** (0.0136)	-0.00395 (0.00469)	-0.0345** (0.0147)	-0.0366*** (0.0138)	-0.0401*** (0.0136)	-0.0448*** (0.0151)	-0.0465*** (0.0161)
Observations	173	173	173	173	173	173	173
Results of the effect of AfT flows for productive capacities on TFP							
Log(AfTPR)	0.0325** (0.0135)	0.00753* (0.00407)	0.0216 (0.0149)	0.0249* (0.0143)	0.0309** (0.0137)	0.0402*** (0.0141)	0.0429*** (0.0144)
PRIE	0.0322 (0.0390)	0.0103 (0.00990)	0.0172 (0.0453)	0.0218 (0.0428)	0.0301 (0.0397)	0.0429 (0.0376)	0.0465 (0.0378)
Log(NonAfT)	-0.0457*** (0.0141)	-0.0105* (0.00539)	-0.0306** (0.0129)	-0.0352*** (0.0129)	-0.0436*** (0.0138)	-0.0565*** (0.0172)	-0.0602*** (0.0179)
Observations	173	173	173	173	173	173	173
Results of the effect of AfT flows for trade policy and regulation on TFP							
Log(AfTPOL)	0.00290 (0.00505)	-0.00169 (0.00151)	0.00544 (0.00592)	0.00459 (0.00566)	0.00348 (0.00525)	0.00116 (0.00486)	0.000557 (0.00491)
PRIE	0.0156 (0.0379)	0.00563 (0.00900)	0.00709 (0.0418)	0.00992 (0.0400)	0.0136 (0.0384)	0.0213 (0.0379)	0.0234 (0.0384)
Log(NonAfT)	-0.0226 (0.0139)	-0.00146 (0.00513)	-0.0204 (0.0130)	-0.0211* (0.0128)	-0.0221* (0.0133)	-0.0241 (0.0166)	-0.0246 (0.0179)
Observations	171	171	171	171	171	171	171

Note: *p-value<0.1; **p-value<0.05; ***p-value<0.01. Robust standard errors are in parenthesis. (a) indicates the location parameters, and (b) refers to the scale parameters.

Table 7: Effect of total AfT flows on the TFP level_Over the full sample
Estimator. Method of Moments Quantile Regression (MMQR)

Variables	Location ^a (1)	Scale ^b (2)	Q10 th (3)	Q25 th (4)	Q50 th (5)	Q75 th (6)	Q90 th (7)
<i>Results of the effect of total AfT flows on TFP for varying levels of PRIE</i>							
[Log(AfT ⁺ TOT)]*PRIE	-0.0309** (0.0137)	0.00107 (0.00504)	-0.0326* (0.0173)	-0.0319** (0.0155)	-0.0309** (0.0137)	-0.0297** (0.0137)	-0.0293** (0.0142)
Log(AfT ⁺ TOT)	0.0725*** (0.0210)	0.00385 (0.00868)	0.0664** (0.0285)	0.0688*** (0.0248)	0.0726*** (0.0209)	0.0766*** (0.0202)	0.0781*** (0.0209)
PRIE	0.574** (0.267)	-0.00920 (0.0974)	0.588* (0.343)	0.582* (0.305)	0.573** (0.266)	0.564** (0.259)	0.560** (0.266)
Log(NonAfI)	-0.0511*** (0.0138)	0.000482 (0.00523)	-0.0518*** (0.0157)	-0.0515*** (0.0144)	-0.0510*** (0.0138)	-0.0505*** (0.0151)	-0.0504*** (0.0161)
Observations	173	173	173	173	173	173	173
<i>Results of the effect of total AfT flows on TFP for varying levels of the combined RDCAP and PRIE</i>							
[Log(AfT ⁺ TOT)]*PRIE*RDCAP	0.00132*** (0.000506)	-0.000386*** (0.000115)	0.00184*** (0.000451)	0.00170*** (0.000459)	0.00148*** (0.000496)	0.000951* (0.000569)	0.000831 (0.000626)
[Log(AfT ⁺ TOT)]*PRIE	-0.0500*** (0.0182)	-0.00105 (0.00505)	-0.0486*** (0.0164)	-0.0490*** (0.0167)	-0.0496*** (0.0174)	-0.0510** (0.0208)	-0.0513** (0.0219)
[Log(AfT ⁺ TOT)]*RDCAP	-0.00258*** (0.000829)	0.000617*** (0.000203)	-0.00341*** (0.000731)	-0.00318*** (0.000755)	-0.00284*** (0.000812)	-0.00199** (0.000935)	-0.00180* (0.00103)
PRIE*RDCAP	-0.0265*** (0.00983)	0.00777*** (0.00220)	-0.0369*** (0.00888)	-0.0340*** (0.00896)	-0.0297*** (0.00967)	-0.0190* (0.0110)	-0.0166 (0.0121)
Log(AfT ⁺ TOT)	0.103*** (0.0305)	0.00643 (0.00752)	0.0942*** (0.0277)	0.0965*** (0.0279)	0.100*** (0.0293)	0.109*** (0.0345)	0.111*** (0.0366)
PRIE	1.015*** (0.357)	0.00146 (0.0994)	1.013*** (0.322)	1.014*** (0.326)	1.014*** (0.341)	1.016** (0.408)	1.017** (0.428)
RDCAP	0.0517*** (0.0159)	-0.0126*** (0.00377)	0.0685*** (0.0143)	0.0639*** (0.0146)	0.0569*** (0.0156)	0.0396** (0.0177)	0.0356* (0.0195)
Log(NonAfI)	-0.0233	-0.0192***	0.00228	-0.00474	-0.0154	-0.0418*	-0.0478*

	(0.0201)	(0.00682)	(0.0216)	(0.0193)	(0.0203)	(0.0229)	(0.0249)
Observations	110	110	110	110	110	110	110
Results of the effect of AfT interventions for productive capacities on TFP for varying levels of the combined RDCAP and PRIE							
[Log(AfTPR)]*PRIE*RDCAP	0.000990 (0.000612)	-0.000307*** (0.000117)	0.00142** (0.000657)	0.00130** (0.000661)	0.00102 (0.000621)	0.000684 (0.000589)	0.000620 (0.000606)
[Log(AfTPR)]*PRIE	-0.0316 (0.0227)	-0.00369 (0.00551)	-0.0264 (0.0253)	-0.0279 (0.0244)	-0.0313 (0.0228)	-0.0353 (0.0223)	-0.0361 (0.0227)
[Log(AfTPR)]*RDCAP	-0.00200* (0.00103)	0.000538** (0.000215)	-0.00275** (0.00111)	-0.00254** (0.00112)	-0.00204* (0.00105)	-0.00146 (0.000994)	-0.00135 (0.00102)
PRIE*RDCAP	-0.0195* (0.0112)	0.00559*** (0.00207)	-0.0273** (0.0120)	-0.0251** (0.0121)	-0.0200* (0.0114)	-0.0139 (0.0108)	-0.0127 (0.0111)
Log(AfTPR)	0.0731** (0.0368)	0.00861 (0.00954)	0.0610 (0.0430)	0.0643 (0.0409)	0.0723* (0.0371)	0.0817** (0.0351)	0.0835** (0.0358)
PRIE	0.643 (0.422)	0.0717 (0.102)	0.542 (0.470)	0.570 (0.453)	0.636 (0.424)	0.714* (0.415)	0.729* (0.422)
RDCAP	0.0390** (0.0185)	-0.00972*** (0.00369)	0.0527*** (0.0199)	0.0489** (0.0200)	0.0399** (0.0188)	0.0293* (0.0178)	0.0273 (0.0183)
Log(NonAfT)	-0.0214 (0.0194)	-0.0192*** (0.00622)	0.00564 (0.0225)	-0.00181 (0.0210)	-0.0196 (0.0202)	-0.0405** (0.0196)	-0.0446** (0.0206)
Observations	110	110	110	110	110	110	110

Note: *p-value<0.1; **p-value<0.05; ***p-value<0.01. Robust standard errors are in parenthesis. (a) indicates the location parameters, and (b) refers to the scale parameters.

Appendix 1: Definition and source of variables

Variables	Definition	Source
TFP	This is the measure of total factor productivity (TFP) level at current purchasing power parity (USA=1). It shows relative TFP across countries.	Penn World Tables PWT 10.01 (see Feenstra et al., 2015).
AFTTOT, AFTINF, AFTPR, AFTPOL	<p>"AFTINF" is the real gross disbursements of Aid for Trade allocated to the buildup of economic infrastructure. "AFTPR" is the real gross disbursements of Aid for Trade for building productive capacities.</p> <p>"AFTPOL" is the real gross disbursements of Aid allocated for trade policies and regulation.</p> <p>"AFTTOT" is the total real gross disbursements of total Aid for Trade. It is the sum of the three components of the official development aid described above. All four AfT variables are expressed in constant prices 2020, US Dollar.</p>	<p>Author's calculation based on data extracted from the OECD statistical database on development, in particular the OECD/DAC-CRS (Organization for Economic Cooperation and Development/Donor Assistance Committee)-Credit Reporting System (CRS). Aid for Trade data cover the following three main categories (the CRS Codes are in brackets):</p> <p>Aid for Trade for Economic Infrastructure ("AFTINF"), which includes transport and storage (210), communications (220), and energy generation and supply (230);</p> <p>Aid for Trade for Building Productive Capacity ("AFTPR"), which includes banking and financial services (240), business and other services (250), agriculture (311), forestry (312), fishing (313), industry (321), mineral resources and mining (322), and tourism (332); and</p> <p>Aid for Trade policy and regulations ("AFTPOL"), which includes trade policy and regulations and trade-related adjustment (331).</p>

NonAFT	This is the measure of the development aid allocated to other sectors in the economy than the trade sector. It has been computed as the difference between the gross disbursements of total official development assistance (ODA) and the gross disbursements of total Aid for Trade (both being expressed in constant prices 2020, US Dollar).	Author's calculation based on data extracting from the OECD/DAC-CRS database.
PRIE	This is the effective patent protection (PRIE) computed as the index of Patent Protection (PRI) multiplied by the index of effectiveness of legal of contracts.	<p>The indicator "PRI" is developed by Park (2008) see data online at: http://fs2.american.edu/wgp/www/</p> <p>Data on the index of legal enforcement effectiveness is extracted from the Fraser Institute (https://www.fraserinstitute.org/economic-freedom/dataset) (see Gwartney et al., 2022)</p> <p>Note that values of "PRI" in the database of Park (2008) range between 0 and 5, while in the database of the Fraser Institute, the values of the index of legal enforcement of contracts range between 0 and 10. Following Liu et al. (2021), to compute the indicator of "PRIE", we use the index of legal enforcement deflated by 10 so that its values range now between 0 and 1.</p>
ECI	This is the economic complexity index. It reflects the diversity and sophistication of a country's export structure, and hence indicates the diversity and ubiquity of that country's export structure. It has been estimated using data connecting countries to the products they export, and applying the methodology in described in Hausmann and Hidalgo (2009). Higher values of this index reflects greater economic complexity.	MIT's Observatory of Economic Complexity (https://oec.world/en/rankings/eci/hs6/hs96)
GDPC	Per capita Gross Domestic Product (constant 2015 US\$).	World Development Indicators (WDI) of the World Bank

RDCAP	This is the indicator of the per capita research and development (R&D) expenditure (constant 2015 US\$). It has been obtained by multiplying the indicator of R&D intensity (i.e., the share of research and development expenditure in GDP, not expressed in percentage) by the real per capita GDP (constant 2015 US\$).	WDI
HUM	This is the indicator of human capital. It is measured by the number of years of schooling and returns to education.	Penn World Tables PWT 10.01 (see Feenstra et al., 2015).
GCONS	This is the ratio (in percentage) of the general government final consumption expenditure to GDP.	WDI
FDI	This is the indicator of the net inflows of FDI (in percentage of GDP)	WDI
TERMS	This is the indicator of TERMS of trade, measured by the net barter TERMS of the trade index (2000 = 100).	WDI
TRCOST	<p>This is the indicator of the average comprehensive (overall) trade costs. We have calculated the average overall trade costs for a given country in a given year, as the average of the bilateral overall trade costs on goods across all trading partners of this country.</p> <p>Data on bilateral overall trade costs has been computed by Arvis et al. (2012, 2016) following the approach proposed by Novy (2013). Arvis et al. (2012, 2016) have built on the definition of trade costs by Anderson and van Wincoop (2004), and considered bilateral comprehensive trade costs as all costs involved in trading goods (agricultural and manufactured goods) internationally with another partner (i.e., bilaterally) relative to those involved in trading goods domestically (i.e., intranationally). Hence, the bilateral comprehensive trade costs indicator captures trade costs in its wider sense, including not only international transport costs and tariffs but also other trade cost components discussed in Anderson and van Wincoop (2004), such as direct and indirect costs associated with differences in languages, currencies as well as cumbersome import or export procedures. Higher values of the indicator of average overall trade costs indicate higher overall trade costs.</p> <p>Detailed information on the methodology used to compute the bilateral comprehensive trade costs could be found in Arvis (2012, 2016), as well as in the short explanatory note accessible online at: https://www.unescap.org/sites/default/d8files/Trade%20Cost%20Database%20-%20User%20note.pdf</p>	<p>Author's computation using the UNESCAP-World Bank Trade Cost Database. Accessible online at: https://www.unescap.org/resources/escap-world-bank-trade-cost-database</p>

INFL	This is the transformed indicator of the inflation rate.	Author's calculation based on data from the WDI.
POPGR	Population growth rate (in percentage)	WDI
INST	This is the variable capturing the institutional and governance quality.	Author's calculation based on data from the from World Bank Governance Indicators (see Kaufmann et al. 2010).

Appendix 2: Descriptive statistics on variables used in the analysis over the full sample

Variable	Observations	Mean	Standard deviation	Minimum	Maximum
TFP	173	0.564	0.228	0.083	1.331
AfTTOT	173	228	368	1.505	2610
AfTINF	173	131	223	0.238	1410
AfTPR	173	93.5	163	1.168	1520
AfTPOL	171	4.916	20.3	0.007	260
PRI	173	3.087	0.616	1.200	4.675
PRIE	173	1.233	0.523	0.000	2.655
TRCOST	170	318.406	53.694	189.097	460.931
ECI	143	-0.360	0.663	-2.002	1.132
RDCAP	110	21.921	26.554	0.3217	138.145
NonAfT	173	782	947	9.734	7410
HUM	173	2.151	0.527	1.102	3.239
POPGR	173	1.820	1.049	-0.813	6.293
INFL	173	1.927	0.657	0.381	4.240
GCONS	173	14.082	4.071	2.906	30.566
FDI	173	3.466	3.481	-1.462	30.373
TERMS	173	123.920	44.317	26.424	395.808
INST	173	-1.050	1.399	-4.234	2.872

Note: The variables "AfTTOT", "AfTINF", "AfTPR" and "AfTPOL" are expressed in million US dollars.

Appendix 3: List of countries used in the full sample and the sub-sample of LDCs

Full sample		
Angola**	Guatemala	Peru
Argentina	Honduras	Philippines
Benin**	India	Rwanda**
Bolivia	Indonesia	Saudi Arabia
Botswana	Iran, Islamic Rep.	Senegal**
Brazil	Iraq	Sierra Leone**
Burkina Faso**	Jamaica	South Africa
Burundi**	Jordan	Sri Lanka
Cameroon	Kenya	Sudan**
Central African Republic**	Malaysia	Tanzania**
Chile	Mauritania**	Thailand
China	Mauritius	Togo**
Colombia	Mexico	Tunisia
Costa Rica	Morocco	Turkiye
Cote d'Ivoire	Mozambique**	Ukraine
Dominican Republic	Nicaragua	Uruguay
Ecuador	Niger**	Venezuela, RB
Egypt, Arab Rep.	Nigeria	Zambia**
Eswatini	Panama	Zimbabwe
Fiji	Paraguay	

*Note: LDCs are marked with "***".*