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ABSTRACT
The knowledge-capital model of foreign direct investment implies that countries with relatively large outward FDI stocks should also have a relative abundance of proprietary knowledge assets. Early versions of the knowledge-capital theory model these assets as if they were only the results of knowledge investments by private firms. We extend the theory by modelling the public-private interaction in knowledge development. This sheds light on the role of the origin country of multinationals. The paper extracts four testable predictions from the model. We to use the inter-country variation in national knowledge-creation systems and foreign-investment performance to test the model. After developing a new dataset that holds knowledge-creation indicators for about 200 countries over the period 2000-2020, we apply a range of non-parametric tests to test the model predictions. Our findings confirm the basic tenet of the knowledge-capital model and show the important role of public knowledge production for outward FDI.

Keywords: business innovation; public knowledge creation; foreign direct investment; knowledge capital; empirical test; worldwide scope

JEL codes: D22; D25; D83; F23; O31; O34

Introduction

> "*The importance of intangible assets to understanding multinationals is acknowledged but remains a conceptual and theoretical curiosity due to the difficulties in observing and measuring the existence and contribution of these assets*" (Davies and Markusen, 2021)

The knowledge-capital theory of foreign direct investment explains outward foreign direct investment (FDI) from the firms' desire to better exploit their firm-specific knowledge assets. Multinational firms have unique non-rival knowledge-capital assets that may --with little additional costs-- be applied in new foreign subsidiaries, thereby increasing the returns to these intangible assets (Markusen, 2002, 2001, 1984; Carr *et al*., 2001; Markusen and Maskus, 2003). Our paper sets out to test an important corollary of this theory: *if the knowledge-capital theory of foreign direct investment is correct, countries with relatively large outward FDI stocks should also have a relative abundance of firm-specific knowledge assets*.

It would be relatively easy to come up with some case studies that find evidence that fits with the knowledge-capital (KC) theory of FDI. However, a general test of this theory can only be convincing if it uses the variation across countries. It is not the lack of international data on outward FDI that is a problem, because these data are becoming better every year. The real obstacle for a general test is the availability of reliable and internationally comparable data for each country's '*relative abundance of firm-specific knowledge assets*'. The main contribution that we aim at in this paper is to develop a methodology for measuring the relative abundance of these knowledge assets, thus addressing the problem that Davies and Markusen (2021) formulate in the opening quotation of this introduction. We apply our methodology in several non-parametric tests, using a new database on national knowledge-developing activities for a large set of countries. Our results offer strong support for the KC theory of outward FDI.

The validity of the KC theory of foreign direct investment has been debated in the literature over the last two decades. The authors of the theory initially came up with a narrowed-down empirical indicator for knowledge assets, namely the skill-related wage differences between countries (Carr *et al*., 2001). This approach was soon put into question by Blonigen *et al*. (2002). They argue that the average skilled labour costs is a measure that may give multi-interpretable results with respect to the drivers of foreign direct investment. Later on, several others joined in this debate (Braconier *et al*., 2005; Tanaka, 2007; Mariel *et al*., 2009; Chellaraj and Mattoo, 2009; Kristjansdottir, 2010). With the benefit of hindsight, the choice for skill-related wages (as indicator for the relative abundance of knowledge assets) was not a lucky one. Firstly, wage differences form a separate motive for FDI decisions, quite apart from intangible knowledge assets. International wage differences are relevant for both unskilled and skilled labour.[1] Secondly, micro-econometric studies have shown that multinational enterprises tend to pay

[1] Exemplified by the rise of software production in India and other emerging countries (Arora and Gambardella, 2005).

premium wages above the national averages.[2] So, international differences in average skill-related wages might tell little about the FDI drivers. Thirdly, the role of skill-related wage differences may differ by type of FDI. Vertical FDI, which is about upstream or downstream production processes, could be sensitive to wage levels. This might also be the case for global value-chain investments, and for export-platform types of FDI. On the other hand, for so-called horizontal FDI, which is mainly motivated by acquiring foreign market shares, the international wage differences may be next to irrelevant. And the latter type of FDI forms the bulk of all FDI transactions (Ramondo *et al.*, 2012). The upshot is that the skill-related wage gap must be regarded as an unfit indicator for the relative abundance of knowledge assets.

But what alternatives are available? Reliable and internationally comparable data on firm-level knowledge assets are still sparse in supply. The preferred choice would be to use direct firm-level data on the value of proprietary knowledge assets. However, international datasets use company data that are affected by different national disclosure and reporting rules. Moreover, companies themselves may be reticent to publish the true value of such a strategic item as their knowledge assets. Hall (2000) proposed to measure the intangible assets of firms via the difference between market value and historic costs. Indeed, Chen et al. (2005) find that market value and intellectual capital of firms tend to be positively related. However, the valuation itself may be difficult due to the inherently tacit nature of knowledge and the uncertainty that surrounds its contant value.[3] Accounting practice often excludes the intangibles component of this knowledge capital.[4] With regard to FDI, the proposal to use the market value as yardstick is problematic. Separate data on market values of foreign subsidiaries and their parents are not available, not even for the USA (McGrattan and Prescott, 2010). When intangible knowledge assets can be used both at home and in the foreign subsidiaries, the risk of a double-counting bias is looming large using the indicator that Hall proposes.

The present situation is that the knowledge-capital theory of outward FDI is still untested with regard to the aforementioned central corollary.[5] We propose to measure the relative abundance of firm-specific knowledge assets by focussing on the measurable inputs of these knowledge assets. Firms benefit from public and semi-public investments in human capital, science and technology. They 'encapsulate' knowledge elements from public and semi-public origin, and recombine them with their private know-how. These inputs are measurable at the national level. If our conjecture is correct, the indicators for public knowledge-creation activities could effectively capture the relative abundance of

[2] Aitken *et al*., 1996; Bernard *et al.* 2018; Wagner, 2012; Kox and Rojas, 2010; Egger and Kreickemeier, 2013; Tanaka, 2015.

[3] Morck and Yeung, 1991; Ali and Hwang, 2000; Foster *et al*., 2012; Chan and Cheung, 2022.

[4] See Corrado et al., 2009; Lev, 2001.

[5] For instance, McGrattan and Prescott (2009, 2010) did not provide a convincing empirical estimate for the central variable in their knowledge-capital model. To demonstrate the plausibility of their model, they use a numeric model exercise, calibrated on FDI stock data of only the USA, while a real test should use the inter-country variation. Anderson *et al*. (2019) adopt the McGrattan and Prescott approach, but they offer no solution to the measurement issue.

knowledge assets of a country's multinational firms.[6] To facilitate a systematic and rigid procedure, we first model the connections between public and private (firm-specific) knowledge development in a dynamic input-output framework, with behavioural parameters that may differ by country. The model yields four testable predictions. The latter are subsequently tested by non-parametric methods, followed by several robustness tests with different country samples.

The main result is that we find unequivocal empirical support for the knowledge-capital theory of outward FDI. A further finding is that a country's outward FDI position correlates stronger with indicators for public knowledge creation than with the available indicators for firm-level knowledge creation. From a methodological perspective, our results show that it is important to ensure that all indicators for knowledge development are de-scaled. This can be done by expressing the indicators per unit of a relevant indicator of national scale (like GDP, total employment, exports or population).

Our paper contributes in several ways to the literature. Firstly, we extend Markusen's (2002) knowledge-capital by formalizing the interaction between public and firm-level knowledge development via an input-output framework. The model allows to derive a number of specific, testable hypotheses. Secondly, we show that it is important to focus on the relative rather than the absolute abundance of knowledge assets of a country, by taking out the impact of national scale. This allows to meaningfully compare countries of different size. It solve an identification and endogeneity problem that has so far encumbered the empirical tests of the KC model: the scale of a national economy affects both national knowledge stocks and the volume of outward FDI.[7] The third contribution is that we provide a data profile of national knowledge-creation systems (both public and private) for over 200 countries and geographical entities for the period 2000-2020. The database includes about eighty indicators for the intensive and extensive knowledge-creation margin of countries.[8] Fourthly, our paper contributes the first empirical test of the KC model of outward FDI that accounts for the international variation in national knowledge-creation efforts (both public and firm-specific). The tests that we did supports the basic corollary of the KC model. Fifthly, we provide several robustness checks for our findings (different specifications of the FDI variable, different country samples). One test shows that our results are not driven by FDI that is motivated by tax evasion or tax sheltering.

The paper has the following structure. Section I presents a formal model of the interaction between public and private knowledge creation and FDI. The model is used to derive falsifiable hypotheses that allow to test the predictions of the KC model. Section II deals with the identification problem, the setup of the empirical tests, and describes the dataset of knowledge-creation indicators. Section III presents the main empirical results based on non-parametrical rank correlation analysis. Section IV checks the robustness of the findings by redoing the analysis for three alternative country samples and alternative specifications of the FDI variable. Section V wraps up the main findings and their

[6] The approach is more or less similar to the valuation of public capital stocks through measuring their main inputs, as is done in the system of national accounts.

[7] We solved this measurement problem by distinguishing between the intensive and the extensive margin of national knowledge creation. The extensive margin measures the role of national scale. Indicators for the intensive margin of knowledge creation are 'de-scaled' and provide a measure of knowledge creation per unit of economic activity.

[8] The database will be made available for replication studies after contacting the author.

implications. Annex I provides the mathematical proofs of some model elements. Annex II documents the data sources for the knowledge-system indicators. The Online Appendix holds the detailed rank correlation results per indicator, per FDI definition, and per country sample.

I. Modelling the interaction between national knowledge systems and outward FDI

Multinationals form part of the national knowledge systems in their countries of origin.[9] In Markusen's KC model, firms command a unique stock of proprietary technology capital. The production of such assets requires fixed-cost investments by the firm itself, but once created, at least a part of the knowledge assets may also be applied in foreign subsidiaries. His model does not elaborate on the inputs in and the production of the firm's proprietary technology capital. Burstein and Monge-Naranjo (2009) argue that the international mobility of managerial know-how constitutes the kernel of firm-embedded productivity' of multinational companies.[10] In the same vein, Yeaple (2023) stresses the role of the multinational's organizational capacity --that is fixed in its institutional structure, corporate culture, and established routines-- as the basis for multinational production. All three approaches have in common that the firm is studied more or less as an island, independent of its surroundings. While Markusen stresses the role of non-rival firm knowledge assets, the two other authors emphasize their intra-company scarcity and non-reproducibility. A fast-rising volume of new literature focuses, however, on the knowledge interaction between individual firms and their environment, particularly in their origin countries. It shows that the competitive edge of individual firms at least partly rests on the knowledge products and knowledge transfers from the public sector, especially the basic science research that it initiates and finances.[11] The public and semi-public sector includes universities, specialized scientific, technical and creative institutes, think-tanks, government bodies, higher-education system, and technology transfer mechanisms that are at least partly financed from tax receipts.

This section specifies a formal framework for analysing the interaction between public knowledge creation and the proprietary knowledge assets of firms. The national knowledge system can be seen as an input-output process with two sub-systems, the public and the firm-based sub-system. Their input side accounts for human and material resources that are dedicated to creating new knowledge and to the re-activation of previously created knowledge. And they have an output side, where knowledge products, education achievements, technologies, a learning-oriented institutional environment or private knowledge assets 'pop out' . In between, there is a throughput and processing phase where efficiency, focusing, and incentives for creativity matter (Akcigit and Goldschlag, 2023). Countries

[9] Freeman (1987) defines national knowledge systems as "the network of institutions in the public and private sectors whose activities and interactions initiate, import, modify and diffuse new technologies". See also OECD, 1997.

[10] "Managerial know-how shapes the productivity of firms [..]. This know-how is costly to reproduce but can be imported from abroad [..]. [F]irm-embedded productivity can be reallocated across sectors, regions and, albeit imperfectly, across countries" (Burstein and Monge-Naranjo (2009).

[11] Sheer, 2022; Arora *et al.*, 2022, 2021; Fagerberg *et al*., 2012.

may differ a lot in the operation of their knowledge systems, and in the balance between the public and private sub-system.[12]

The public knowledge sub-system forms tends to be generous with its products. It forms an important source of free knowledge externalities by generating and disseminating innovations and discoveries via publications, congresses, staff mobility, intermediary supplier networks, and education-related activities.[13] The commercial exploitation of public-held patents is still a rare phenomenon in most countries.[14] These patents are often, before expiration given away, or transferred to domestic firms at favourable conditions.[15] Effectively, this means that most knowledge products from the public and semi-public sector can be characterized as non-proprietary and outside the market domain. By contrast, the firm-based sub-system works almost exclusively on the basis of proprietary knowledge capital. After absorbing free knowledge produced by the public and semi-public sector, firms 'encapsulate' and recombine these input elements with firm-specific knowledge, thus creating marketable products, technologies, brands, and even new business models.

We now proceed by formalizing this process. M_{it} is the currently active knowledge-capital stock of country i at time t. It is a cumulative product of current and past innovation and knowledge development. "Currently active" emphasizes that knowledge from the past is perishable. Active knowledge requires constant refreshment, re-education, reappropriation, re-transfer, documentation and dissemination actions by the current generation, otherwise it decays and becomes dead knowledge.[16] Also the knowledge re-production process is regarded as an economic process that uses inputs and produces outputs. Knowledge has no self-evident dimension of measurement; it is complex and multi-dimensional. But we may express all input costs as a fraction of national GDP and the same goes for the value of outputs. The national knowledge stock consists of a public component (G_{fit}) and a (proprietary) firm-based component (M_{pit}):

$$M_{it} \equiv G_{fit} + M_{pit} \tag{1}$$

Both components are decomposable. We assume that a national economy has just two sectors, the public sector (suffix p) and the firm sector (suffix f). The public sector produces all public, non-proprietary knowledge, while the firm sector accounts for all proprietary or private knowledge. We start with the public sub-system. The knowledge production in the public sub-system is described in Table 1. It combines four sub-processes: creation new public knowledge, acquiring foreign (suffix R) public knowledge, obtaining foreign proprietary knowledge, and re-activation of earlier obtained (old) public

[12] For the differences between countries in the organisation of national innovation systems and in the interaction of public and private research, see Moncada, 2016 and Moncada *et al.*, 2010.

[13] Cf. Gerbin and Drnovsek, 2016; Audretsch and Stephan, 1996, 1999; Arundel *et al*., 2013; Breschi and Catalini, 2010; Toole and Czarnitzki, 2010; Verhoogen, 2021; Keller, 2004.

[14] Agrawal and Henderson, 2002; Calderini *et al*., 2007; Perkmann *et al*., 2013.

[15] Mazzucato, 2014; Arundel *et al*., 2013; Escalona Reynoso, 2010; Maskus and Reichman, 2004; Boyle, 2003a, 2003b; Carlsson and Fridh, 2002; Cohen *et al.*, 2000; Henderson *et al*., 1998.

[16] On historic examples of lost knowledge, see Debenham, 2002; Liu and Kuan, 2016.

knowledge. Each row of the table should be interpreted as an equation, so for instance, the first row must read as:

$$M_{piit} = v_{it} \,.\, \beta_{it}\,(Y_{it})$$

in which Y_{it} represents country *i*'s GDP at time *t*. The parameters β_{it}, φ_{it} and ψ_{jit} all deal with net growth and upgrading of public knowledge-capital in the current period. The inputs are expressed as a

Table 1 The knowledge production process in the public sub-system (for country i in period t)

Sub-processes	Input resources, expressed as fraction of GDP (Y_{it})	Throughput efficiency	Output aggregates
creation new public knowledge	β_{it}	v_{it}	M_{piit} (newly-created public knowledge)
acquiring foreign (*R*) public knowledge	ψ_{it}	v_{it}	M_{pRit} (newly acquired foreign public knowledge) &)
obtaining foreign (*R*) proprietary knowledge	φ_{it}	v_{it}	M_{fRit} (newly acquired foreign proprietary knowledge) &)
re-activation of old public knowledge	ε_{it}	v_{it}	M_{io} (re-activated old public knowledge)
Total public in- and output	$\beta_{it} + \varphi_{it} + \psi_{it} + \varepsilon_{it}$	v_{it}	$M_{pit} = M_{piit} + M_{fRit} + M_{pRit} + M_{io}$

Legend: &) For simplicity we assume that all foreign knowledge assets are sourced and acquired via the public knowledge sector.

fraction of domestic GDP. $\beta_{it} > 0$ represents the GDP fraction dedicated to domestic knowledge creation (like university research, public R&D, basic research). Parameter φ_{it} quantifies the public input costs of attracting foreign proprietary knowledge assets M_{fRit} through the channel of inward FDI.[17] Similarly, ψ_{jit} represents the input costs of accessing and using foreign public, non-proprietary knowledge (M_{pRit}). Finally, GDP fraction $\varepsilon_{it} > 0$ represents the costs of all activities that are dedicated to keep 'old' public knowledge assets active (education, knowledge transfer, documentation, idea diffusion and dissemination activities).[18]. Quantity M_{io} represents country i's public knowledge stock that was built up before the current period *t*. It represents the path-dependent historical continuity in a country's public knowledge system.[19] The older knowledge assets are subject to a depreciation rate δ_{it} and a phasing-out process after *N* years. A higher depreciation rate can be regarded as a form

[17] Cf. Vujanovic *et al.*, 2022; Lu *et al*., 2017.

[18] The parameters φ_{it} and ψ_{jt} deal with international diffusion. We do not require a fixed international knowledge frontier; it may differ by knowledge sub-domain. Benhabib *et al*. (2021) elaborate on the aspect of knowledge diffusion.

[19] Annex 1 elaborates on the depreciation method. Annual cohorts of country *i*'s stock of older public knowledge capital can be consistently aggregated by a CES aggregator: $M_{io} = [\, a_1\, M_{i,t-1}^{1-\sigma} + a_2\, M_{i,t-2}^{1-\sigma} + \ldots + a_{N-1}\, M_{i,t-(N-1)}^{1-\sigma}]^{\,(1/1-\sigma)}$ in which $\sigma > 1$ is the elasticity of substitution and $a_1 \ldots a_n$ represent the size shares of the annual knowledge stock cohorts, summing up to one, as proposed by Benhabib (2019).

of creative destruction.[20] Between the input and out columns, we see the column throughput efficiency, symbolised by dimensionless factor $v_{it} > 0$. It depicts the efficiency with which financial inputs are converted into knowledge outputs. For modelling transparency, we assume that v_{it} is the same for all four sub-processes. It may, for instance, depend on knowledge-absorption capabilities, creativity incentives, legal and institutional framework, labour productivity, connectivity, and overall national efficiency.

The final row of Table 1 gives the aggregates for knowledge-producing inputs and outputs. The implicit equation for this last row is:

$$M_{pit} = M_{piit} + M_{fRit} + M_{pRit} + M_{io} = v_{it}(\beta_{it} + \varphi_{it} + \psi_{it} + \varepsilon_{it})Y_{it}$$

Analog to the public sub-system, Table 2 describes the production function of firm-owned proprietary knowledge assets. Country i has s ∈ $1, .., S$ firms that differ by organisational creativity, productivity, and management capabilities. These elements are embodied in the firm-specific fixed effect $z_s > 0$.

Table 2 Knowledge production process in the firm-based sub-system (disaggregated by firm* s *in country i in period t)

Sub-processes	Input resources, as fraction of GDP (Y_{it})	Throughput efficiency	Output aggregates
internal creation of new private knowledge assets	a_{ist}	$z_s.v_{it}$	G_{siit} (internal, newly created private knowledge)
absorbing of public knowledge inputs	ω_{ist}	$z_s.v_{it}$	$G_{spit} = f(\omega_{ist}M_{pi,t-1})$ (newly encapsulated domestic public knowledge inputs) [&])
re-activation of 'old' private knowledge	ε_{ist}	$z_s.v_{it}$	G_{iso} (re-activated 'old' private knowledge)
aggregate effort of firms	$\sum_s \alpha_{ist} + \omega_{ist} + \varepsilon_{ist}$	$z_s.v_{it}$	$G_{fit} = \sum_s G_{siit} + G_{spit} + G_{iso} = \sum_s G_{sit}$

Legend: [&]) Firms do not use the very latest public knowledge 'cohort', but a recent knowledge cohort. This is not only plausible but it also prevents endogeneity loops within the model.

[20] It reduces the weight of older knowledge stocks and thus contributes to the rejuvenation of public knowledge stocks. The speed of annual knowledge-rejuvenation is determined by $(\beta_{it} + \varphi_{it} + \psi_{it})\ \delta_{it}$.

Firms in country *i* are subject to the national throughput efficiency v_{it}, but mitigated at firm level by their z_s factor.[21] Hence, the country- and firm-specific throughput factor becomes $z_s.v_{it}$. The firm-level production process of knowledge has three sub-processes: internal creation of new private knowledge assets, absorbing of public knowledge inputs, and re-activation of 'old' private knowledge. G_{siit} is proprietary new knowledge that results from the firm's own activities (R&D, design, in-house specialists, process or product expertise). G_{spit} is the firm-level result from encapsulating knowledge products from domestic public sources. G_{iso} captures re-activated older knowledge stocks of a firm. The parameters $(a_{ist}, \omega_{ist}, \varepsilon_{ist})$ are firm-specific and strictly positive; they depict the inputs into the sub-processes of the firm's knowledge-related activities. The first two parameters describe inputs into the creation of new proprietary knowledge assets. Parameter a_{ist} captures firm-level R&D, and the development of new product varieties, marketing concepts or business models. Parameter ω_{ist} deals with two elements of the firm's knowledge production process. The first is the absorption of recent public knowledge developments, which may include networking, setting up learning projects, or the hiring of specialists to master new knowledge areas. Moreover, ω_{ist} also captures the costs of combining the new inputs from the public sector with existing knowledge assets of the firm, and the costs of turning the firm-modified public knowledge inputs into excludable private assets, e.g. through patenting or secrecy measures.[22] The older cohorts of the firm's intangible assets (G_{iso}) are subject to depreciation rate δ_{ist} and a phasing-out process after N years, similar to the public knowledge system.[23] The last row in Table 2 describes the aggregation over all *S* firms in country *i*. The implicit equation can be expressed as a function of the throughput efficiency and real input costs:

$$G_{fit} = \sum_{s} G_{siit} + G_{spit} + G_{iso} = \sum_{s} G_{sit} = v_{it} Y_{it} \sum_{s} z_s \, (\alpha_{ist} + \omega_{ist} + \varepsilon_{ist})$$

G_{fit} represents the aggregate active proprietary knowledge of all firms in country *i* at time *t*. In the perspective of Markusen (2002), the inputs of G_{fit} would mainly consist of fixed-cost items with an investment nature.

Both Tables 1 and 2 contain a lagged, path-dependent component (M_{io}, G_{io}) of, respectively, public and firm-level knowledge capital. These variables have a vintage structure, to which each year a new knowledge 'cohort' is added while older 'cohorts' are depreciated and eventually discarded. The vintage structure creates a historical inertness of a country's knowledge stocks with respect to real-time GDP changes. The time dynamics of knowledge stocks can be complex due to the time variance of GDP

[21] A typical result from microeconometric studies is that firms with multinational activities have a higher productivity than most exporting firms, and substantially higher than firms that operate solely on their national market. Cf., Wagner, 2012; Kox and Rojas, 2010; Bernard *et al*., 2018, 2013; Helpman *et al*., 2004.

[22] Cf. Crouset *et al*., 2022.

[23] The aggregation of G_{io} may be more problematic than holds for M_{io}, because all firm-specific G_{iso} cannot be added up in a simple way. Their valuation could contain a substantial double-counting bias if knowledge assets are based on ('created from') the same public knowledge assets (cf. Arora *et al.*, 2022). In that case, they are 'variations on a theme' rather than original innovations (cf. Crouset *et al.*, 2022), and their aggregation should contain a nested sub-system that distributes these variations.

and time variance in the behavioural parameters (as specified in Tables 1 and 2). We may take out the time variance of the behavioural parameters to clarify the basic time dynamics.

Proposition 1 *If behavioural parameters are time invariant, the development of public knowledge stocks (M_{pit}) has the following dynamics:*[24]

$$M_{pit} = v_i\,(\beta_i + \varphi_i + \psi_i)\;A_i\;Y_{it} \tag{2}$$

in which A_i is a factor that abbreviates the amortization and re-activation efforts for older vintages of knowledge assets in country *i* 's public sector: $A_i \equiv \{1 + \varepsilon_i\,(1 - \delta_i)\,X_{Yt}\}$, with X_Y as a chain index that links scale (GDP) changes over time.

The time pattern for the development of proprietary knowledge stocks of firms (G_{fit}) is slightly more complicated. The sub-process G_{spit} has our main attention, namely the firm's absorbing of public knowledge inputs. This sub-process adds an additional time lag to the dynamic cycle.

Proposition 2 *If behavioural parameters are time invariant, the time development of aggregate proprietary knowledge stocks of firms (G_{fit}) has the following dynamics*:

$$G_{fit} = v_i\,Y_{it}\,\textstyle\sum_s z_s\,A_{is}\big[\,\alpha_{is} + \omega_{is}\,v_i\,(\beta_i + \varphi_i + \psi_i)\,A_i\,Y_{i,t-1}\big] \tag{3}$$

The term A_{is} abbreviates the amortization and re-activation module for older proprietary knowledge cohorts at the level of firms: $A_{is} \equiv \{1 + \varepsilon_{is}\,(1 - \delta_{is})\,X_{Yt}\}$. The proof of Proposition 2 is given in Annex I. It shows that a country's outward FDI depends on private and public knowledge-creation activities, and that firms should not be considered as isolated and self-sufficient entities. Proposition 2 formalizes the crux of our extension to Markusen's knowledge-capital model of FDI.

Individual firms exploit their proprietary knowledge assets (G_{sit}) in the domestic market. But they also use it abroad via outward FDI, if this increases their expected profits (ΔR^*_{is}).[25] If the profit condition is satisfied, the firm's willingness to supply its proprietary knowledge assets to a new foreign subsidiary in country *j* is almost unbounded. From this conjecture, and aggregating over all firms, we derive a simple supply function for outward bilateral FDI (from country i to country *j*):

$$FDI^{outw}_{ijt} = \begin{cases} q_{ij}\,\left(G_{fit}\right)^h & if \sum_s \Delta R_{ijst} \geq 0 \\ 0 & otherwise \end{cases} \qquad \forall\, i,j,s \tag{4}$$

with q_{ij} as a constant for each country pair that accounts for factors like language, culture, or remoteness, while *h* is a general reaction parameter holding for all countries. All time-variant bilateral

[24] The proof is given in Annex I.

[25] This assumes that the firm's top management has full knowledge of their proprietary assets. Acemoglu et al. (2007), Rajan and Zingales (2001), and Malenko (2023) show that informational noise in the firm's internal communication channels about the real value potential of these assets leads to sub-optimal decisions. Acemoglu et al. (2007) find evidence that firms that are close to the technological frontier are more likely to set up new establishments and subsidiaries to exploit the proprietary new knowledge assets.

factors like taxes, subsidies, regulations, and country size (linked to GDP) influence bilateral FDI decisions through their (expected) effects on ΔR_{ijs}. Following the IMF definition, a firm has foreign direct investment when it uses its G_{sit} for setting up equity-controlled foreign production ('having a controlling interest').

Given the firms' own assessment of the foreign market potential of G_{sit}, the expected profit change depend on bilateral FDI barriers, on the fixed setup costs for a foreign subsidiary, on the value of any investment facilities offered by the host country, and on possible effects for its own export sales after setting up the foreign subsidiary.[26] The model's reduced-form equation for outward FDI stocks, in the case of positive foreign profits, can be derived as:

$$(5) \quad FDI_{ijt}^{outw} = q_{ij}\, {G_{fit}}^{h} = q_{ij} \left\{ v_i Y_{it} \sum_{s=1}^{S} z_s\, A_{is} \left[\alpha_{is} + \omega_{is}\, v_i\, (\beta_i + \varphi_i + \psi_i)\, A_i\, Y_{i,t-1} \right] \right\}^{h}$$

The right-hand-side specification of equation (5) shows the important role of current and lagged scale effects (Y_{it}, $Y_{i,t-1}$). Another scale effect is hidden in the (so far implicit) assumption that the number of firms (s$\in$1, 2, .., S) is equal in all countries ($S = S_i = S_j$ for $\forall\, i, j$), while in reality it holds that the number of firms is always a positive function of economic scale. To keep the model consistent and transparent we will assume henceforth that all national *S* are scale-corrected. Note that the term after ω_{is} represents the public inputs into the firm's production process of proprietary assets.

Equation (5) offers all elements that are important for our empirical test of the knowledge-capital model. We regard the model as incorrect and falsified if elasticity *h* would have no statistical significance or has a negative sign. Once the general zero hypothesis is rejected, a lot more specific tests become feasible.

We conclude this modelling section by formulating a set of specific and falsifiable predictions from our model. The first and the third prediction directly pertain to Markusen's knowledge-capital model of FDI, while the second and fourth prediction are important tests for our extension to the knowledge-capital model of outward FDI:

1. Firm-specific knowledge assets (G_{fit}) should have a significant and positive impact on a country's outward FDI volume (zero hypothesis).
2. Public knowledge inputs (M_{pit}) into firm-level proprietary knowledge assets should have a significant and positive impact on a country's outward FDI volume.
3. At a lower aggregation level, most individual indicators for a country's 'relative abundance of knowledge capital' should have a positive and statistically significant impact on outward FDI volume. When made scale-free, the empirical indicators for knowledge-capital elements are expected to correlate stronger with outward FDI volume than with domestic GDP.
4. National knowledge-throughput efficiency (v_{it}) should have a positive and significant impact on a country's outward FDI.

[26] Following Arkolakis *et al.*(2018), "*trade costs encourage, while MP costs discourage, multi-plant production*" [NB: *MP* = multinational production, HK].

II. Design of empirical tests and data issues

A country's total knowledge creation is directly affected by its economic scale (GDP), as can be seen in equation (3). The absolute size of a country's economy magnifies its total knowledge output through the number of firms, available investment funds, number of students, public research budgets, numbers of domestic researchers, total patenting actions or the number of universities. Also the country's outward FDI volume is partly driven by the economic size (GDP), as equation (5) shows. For an empirical test of the knowledge-capital theory of FDI, we need to use the inter-country variation. However, we don't want the results to be messed-up by the scale effects. Recall that the main target of this paper is to test the following corollary of the KC model: "*if the knowledge-capital theory of foreign direct investment is correct, countries with relatively large outward FDI stocks should also have a relative abundance of firm-specific knowledge assets".* The emphasis should therefore be on "relative". It implies that the double impact of economic size should be neutralised in our empirical test. The country-scale effect must be identified, quantified and filtered out, before we can meaningfully compare countries of different economic size with regard to their knowledge stocks and FDI.

The first identification challenge is to assess what part of outward FDI stocks of any country *k* is driven by the country's economic scale. We opt for a simple solution by taking a relative performance measure, the ratio of outward FDI stocks per unit of GDP.[27] This variable is labelled OUTST_GDP. The second identification challenge is to isolate the role of scale effects on country *k*'s knowledge creation performance. We introduce the concepts of the intensive and extensive margin of knowledge creation.

Data. For the intensive margin of knowledge, creation we develop scale-free indicators that always measure the *relative* knowledge creation performance, normalized by a relevant scale aggregate (e.g., total employment, gross domestic product, population size, or total exports). Table 3 provides the set of 38 indicators that we will use for the intensive margin of public knowledge creation. The intensive-margin indicators are ordered conform the sub-processes that are distinguished in Table 1. The last category (National productivity and knowledge-throughput efficiency) gives eight indicators for the throughput efficiency per country (variable v_{it} in Table 1).

For the intensive margin of firm-based knowledge creation (per country) we have developed a similar set of indicators, which is presented in Table 4. We would have liked to structure this indicator set conform the sub-processes that are distinguished in Table 2 (internal creation of new knowledge assets, absorbing of public knowledge inputs, and re-activation of 'old' firm-based knowledge). However, data availability did not allow this. Instead, Table 4 presents four input-related and eleven output-related indicators for the intensive margin of firm-based knowledge creation.

[27] The annual data on total outward FDI stocks per country are taken from UNCTAD (2022). The GDP data are from IMF (International Financial Statistics) and World Bank (World Development Indicators). We use data on total FDI positions with immediate partner countries. Bilateral FDI stock data tend to be more reliable, less volatile and more widely available than FDI flow data (Cf. Anderson *et al*., 2019, 2020). Moreover, FDI stocks have a cumulative character like the knowledge capital stocks.

Table 3 Intensive margin of the public knowledge-creation system: Scale-free indicators

Sub-processes of the public knowledge system	Variable description	Variable name
Re-activation of existing public knowledge	Females with advanced education, as % of female working-age population	ADEDU_F
	Males with advanced education, as % of male working-age population	ADEDU_M
	Contribution of labour quality to GDP growth (growth accounting)	LQ_CONTR
	Women researchers as % of total researchers	FEM_RESR
	Number of R&D researchers per million people	TOT_RESR
	Number of R&D technicians per million people	TOT_TECH
Creation of new public knowledge: input indicators	Mean score for Global Innovation Indexes 2011-2020, normalized by GDP in PPP$	GII_MAIN
	Global Innovation subindex for inputs 2020, normalized by GDP (in PPP$ 2019)	GII_INPUT
	Research and development expenditure as % of GDP (curr. prices, USD)	GERCGDP
	Gross domestic expenditure on R&D (GERD) as % of GDP (curr. PPP$)	GERPGDP
	Gross domestic expenditure on R&D (in PPP$), per capita of population	GERD_CAP
	Governm. intramural expenditure on R&D (GOVERD) as % of curr. GDP (PPP$)	GVE_XGDP
	Higher-education expenditure on R&D (HERD) as % of current GDP (PPP$)	HED_XGDP
	Total researchers per thousand of domestic labour force	ALLRES_LF
	Total R&D personnel (incl. staff) per thousand of domestic labour force	RDPERS_LF
	Total researchers per thousand of domestic total employment	ALLRES_EM
	Total R&D personnel (incl. staff) per thousand of dom. total employment	RDPERS_EM
	Gross domestic expenditure on R&D (in PPP$), per capita of population	GERD_CAP
Creation of new public knowledge: output indicators	Global Innovation subindex for outputs 2020, normalized by GDP (in PPP$ 2019)	GII_OUTPUT
	Number of papers in economics, normalized by size of domestic GDP	ECONPAP
	Number of articles in scientific journals, normalized by size of domestic GDP	JRN_ART
	Judicial independence of government, mean score 2000-2019 *)	JUDINDEP
	Impartiality of legal courts, mean score 2000-2019 *)	IMPART_C
	Impartiality of public administration, mean score 2000-2019 *)	IMP_PUBL
	Protection of property rights, mean score 2000-2019 *)	PROTPROP
	Effectiveness legal enforcement, mean score 2000-2019 *)	LEG_FORCE
Acquisition of foreign knowledge	Total inward FDI stocks, normalized by size of domestic GDP	INFDI_GDP
	Import of business and financial services, as % of total services import	BF_IMSRV
	Import of knowledge-intensive business services, as % of total services import	KIBS_IMSRV
	Number of patent applications by non-residents, normalized by GDP	PAT_NRES
	Individuals using the Internet, as % of population	INT_USER
National productivity and knowledge-throughput efficiency	Number of secure Internet servers, per million people	INTSECUR
	Number of fixed broadband subscriptions, per million people	BBND_SUB
	Contribution of ICT assets to GDP growth (growth accounting)	ICT_CONTR
	Labour productivity p. person employed, converted to 2020 PPP$	LP_EMPL
	Labour productivity p. hour worked, converted to 2020 PPP$	LP_HOUR
	Freedom of foreigners to visit, mean score 2000-2019	FORGN_MV
	Freedom to setup up a business, mean score 2000-2019	STARTABUS
	Freedom to setup up a business, mean score 2000-2019	STARTABUS

The indicators cover a period of 21 years, from 2000 to 2020. Not all indicators are available for each country and year. A substantial number of annual country observations is missing, especially for the

small countries with a limited statistical apparatus. In order to get a balanced data set, we have calculated, per indicator and country, the mean value of all available annual observations over the full period 2000-2020. An advantage is that annual measurement errors in country data are 'averaged out'. However, it also implies that the period mean for developed countries is might be based on more annual observations than holds for the small developing countries. This should not be a big problem, because it is documented that the annual variation for knowledge-system indicators tends to be quite small (Van Elk *et al.*, 2019).[28] The empirical indicators measure different, but sometimes partially overlapping elements of a country's knowledge system. For the indicators in Table 3, the average number of country observations per indicator is 116, with 38 as minimum and 171 as maximum. For the indicators in Table 4 the average number of observations is 97, with 38 as minimum and 160 as maximum.

Table 4 Intensive margin of firm-based knowledge creation: Scale-free indicators

Knowledge system sub-processes	Variable description	Variable name
Input-related indicators for knowledge-creation efforts by private business	Total business expenditure on R&D (BERD) as % of current GDP (PPP$)	BERD_GDP
	% of government expenditure on R&D that is performed by the business enterprise sector	BUX_GERD
	% of higher-education expenditure on R&D that is financed by the business sector	BFIN_HERD
	Total business enterprise R&D personnel as a percentage of national total	BRES_TOT
Output-related indicators for knowledge-creation efforts by private business	High-technology exports, as % of total manufacturing exports	HT_MFGEX
	Exports of ICT goods, as % of total merchandise exports	ITPROD_EX
	Exports of ICT services, as % of total services exports	IT_SERVEX
	Export of business and financial services, as % of total services export	BF_SRVEX
	Export of knowledge-intensive business services, as % of total services export	KBS_SRVEX
	No. of patents filed under the PCT (priority yr), per 1000 ppp$ of GDP	PATP_GDP
	No. of ICT patents filed under the PCT (priority yr), per 1000 ppp$ of GDP	PATI_GDP
	No. of biotech patents filed under the PCT (priority yr), per 1000 ppp$ of GDP	PATB_GDP
	Number of patent applications by residents, normalized by GDP	PATP_RES
	Number of trademark applications by direct residents, normalized by GDP	TM_DRES
	Total number of trademark applications, normalized by GDP	TM_TOT

Note: Annex Table II provides details on the original sources of each indicator. The normalisation with a relevant scale aggregate (separate for each country) is in most cases done by this author.

Finally, the extensive margin of knowledge creation is quite straightforward, because it uses nominal values for all knowledge indicators, including the scale effects that are embodied in them. Annex III presents 25 extensive-margin indicators of national knowledge development. The results with the extensive-margin indicators will be compared wit those of the intensive-margin indicators. The comparison sheds light on the importance of data normalisation for assessing the relative abundance of a country's knowledge assets.

[28] This should not be surprising, because the knowledge system is based on long-term processes. It takes some fifteen years to educate engineers or university students with a master's degree.

Testing methodology. To test the model predictions of Section 1, we apply several non-parametric tests. They focus on the ordinal association between a country's knowledge-creation indicators and the same country's outward FDI. Substantial correlation between KC indicators of a country may be expected. It means that they cannot be tested simultaneously, and we run the rank correlation tests separately for each indicator. Kendall's *tau-b* rank correlation coefficient tests the strength of the degree of similarity between the two rankings, and establishes the statistical significance of this similarity relation. The *tau-b* coefficient is well-suited for small samples like ours (maximum number of country observations is 209), in which ties (equal rankings) may occur. The Kendall *tau-b* coefficient is defined as:[29]

$$\tau_B = \frac{n_c - n_d}{\sqrt{(n_o - n_1)(n_o - n_2)}},$$

in which: $n_o = n(n-1)/2$ is the maximum number of possible pairwise combinations, n_c is the number of concordant pairs (correspondance between rank of FDI and indicator score), n_d is the number of discordant pairs (different rank for FDI and indicator score), $n_1 = \sum_i t_i(t_i - 1)/2$ is the occurrence of ties (equal rankings) for FDI, $n_2 = \sum_j u_j\big(u_j - 1\big)/2$ is the occurrence of ties for indicator j, t_i is the number of tied values in the ith group of ties for FDI, and u_j is the number of tied values in the jth group of ties for the ranked indicator that is compared with FDI. *Tau-b* can be applied if the underlying scale of both ranked variables has the same number of possible values. In our case this condition is satisfied, because the rank values refer to the same set of countries. Values of Kendall's *tau-b* range from *−1* (perfect inversed or negative correlation) to *+1* (full perfect positive correlation). A value of zero indicates the absence of any association.

We will also calculate the rank correlation with alternative rank correlation measures (Spearman's *rho*, pairwise correlation). It turned out that these results fully converge with the pattern that displayed by the Kendall *tau-b* scores, but correlation scores are often higher. Since the Kendall′s method is the toughest test, only these results will be presented in the main text; in the Online Appendix also the results for Spearman's *rho* are given.

III. Results

We start by using the most stringent rank correlation test, using only variables that have been fully corrected for scale effects. The dependent variable for FDI is outward FDI stocks per unit of GDP (OUTST_GDP). For the knowledge-system variables we only use the intensive-margin indicators. The average number of country observations per intensive-margin indicator is 110. It is important to stress that in case of full randomness, the probability of a matching ordinal rank with 110 observations would be very close to zero: 1/(110*109) ≈ 0.000083. The results are split in two parts. Table 5a gives the rank correlation results per knowledge domain and per indicator. Table 5b aggregates the detailed results for each of the hypotheses formulated at the end of Section 1.

[29] E.g., Agresti (2010).

Table 5a Rank correlation between outward FDI stocks per unit of GDP (OUTST_GDP) and each intensive-margin indicator, grouped by knowledge domain (full country sample)

Knowledge system sub-processes	Indicator name	No. of compared country observations	Rank correlation, Kendall's *tau-b*	Prob>|z|	Confidence code &)
(Re-)activation of existing public knowledge	ADEDU_F	147	0.200	0.000	***
	ADEDU_M	147	0.118	0.033	**
	LQ_CONTR	119	0.106	0.088	*
	FEM_RESR	36	–0.273	0.020	**
	TOT_RESR	118	0.491	0.000	***
	TOT_TECH	107	0.489	0.000	***
Creating of new public knowledge: input-related indicators	GII_MAIN	134	0.539	0.000	***
	GII_INPUT	122	0.570	0.000	***
	GERCGDP	129	0.404	0.000	***
	GERPGDP	42	0.380	0.000	***
	GERD_CAP	42	0.498	0.000	***
	GVE_XGDP	42	0.008	0.948	
	HED_XGDP	42	0.396	0.000	***
	ALLRES_LF	39	0.439	0.000	***
	RDPERS_LF	38	0.440	0.000	***
	ALLRES_EM	39	0.425	0.000	***
	RDPERS_EM	38	0.460	0.000	***
Creating of new public knowledge: output-related indicators	GII_OUTPUT	121	0.482	0.000	***
	ECONPAP	141	0.412	0.000	***
	JRN_ART	160	0.173	0.001	**
	JUDINDEP	146	0.445	0.000	***
	IMPART_C	146	0.462	0.000	***
	IMP_PUBL	144	0.403	0.000	***
	PROTPROP	146	0.428	0.000	***
	LEG_FORCE	146	0.315	0.000	***
Acquisition of foreign knowledge assets	INFDI_GDP	171	0.295	0.000	***
	BF_IMSRV	138	0.130	0.024	**
	KIBS_IMSRV	161	0.181	0.000	***
	PAT_NRES	136	0.102	0.079	*
National productivity and knowledge-throughput efficiency	INT_USER	167	0.504	0.000	***
	INTSECUR	167	0.484	0.000	***
	BBND_SUB	167	0.479	0.000	***
	ICT_CONTR	117	0.210	0.001	***
	LP_EMPL	119	0.579	0.000	***
	LP_HOUR	119	0.595	0.000	***
	FORGN_MV	146	0.233	0.000	***
	STARTABUS	146	0.346	0.000	***
	BERD_GDP	42	0.352	0.001	***
	BUX_GERD	42	0.273	0.011	**

Input-related indicators for knowledge-creation efforts by private business	BFIN_HERD	42	0.059	0.588	
	BRES_TOT	38	0.374	0.001	***
Output-related indicators for knowledge-creation efforts by private business	HT_MFGEX	156	0.330	0.000	***
	IT_SERVEX	160	–0.086	0.105	
	ITPROD_EX	159	0.304	0.000	***
	BF_SRVEX	135	0.320	0.000	***
	KBS_SRVEX	160	0.064	0.229	
	PATP_GDP	42	0.447	0.000	***
	PATI_GDP	42	0.501	0.000	***
	PATB_GDP	42	0.524	0.000	***
	PATP_RES	129	0.077	0.196	
	TM_DRES	130	–0.117	0.050	*
	TM_TOT	139	–0.145	0.013	**
Legend: [&)] Coding of confidence levels: *** p<0.01, ** p<0.05, * p<0.10.					

Table 5b Overall indicator count statistics with regard to model predictions (full country sample)

Model predictions	Overall count statistics [§)]
1. Firm-specific knowledge assets (G_{fit}) should have a significant and positive impact on a country's outward FDI volume (zero hypothesis)	11 of 15 indicators (73.3%)
2. Public knowledge inputs (M_{pit}) into firm-level proprietary knowledge assets should have a significant and positive impact on a country's outward FDI volume.	27 of 29 indicators (93.1%)
3. Most individual indicators for a country's 'relative abundance of knowledge capital' should have a positive and statistically significant impact on outward FDI volume.	36 of 44 indicators (81.8%)
4. National knowledge-throughput efficiency (v_{it}) should have a positive and significant impact on a country's outward FDI.	8 of 8 indicators (100%)
Legend: [§)] The score reflects the number of rank correlation indicators (Kendall *tau-b*) that comply with the condition in the first column by being statistically significant and having the predicted sign. The numbers in brackets gives the share of the total number of indicators that is relevant for that particular rank correlation. Source: Table 5a	

The evidence in Tables 5a and 5b provide clear support for the knowledge-capital model. We recall that the first and the third prediction directly pertain to Markusen's knowledge-capital model of FDI, The majority of indicator-wise rank correlations support both hypotheses. Almost three in four indicators (73%) are in line with prediction 1. More than four out of five indicators (82%) are in line with prediction 3. The second and fourth predictions deal are specific for our extension of the Markusen KC model. Here the predictions are supported even stronger, namely by 93% (for the role of public knowledge-creation) and 100% (for the role of national and firm-specific productivity indicators). The outcomes for the fourth model prediction confirm that national knowledge-throughput efficiency (productivity, connectivity, openness for knowledge circulation) has a strong and positive impact on outward FDI. Micro-econometric studies have repeatedly concluded that multinational firms

(i.e. active with outward FDI) have a higher productivity performance than firms that operate solely in the domestic market.[30] The direction of causation from national productivity averages to the FDI decision is not *a priori* clear. Productivity could be interpreted as a proxy for national capabilities for process invention and organizational innovation (Burstein and Monge-Naranjo, 2009; Yeaple, 2023). Hence, the high score of productivity indicators in the rank correlation could also reflect the relative abundance of such relevant knowledge assets. Further research would be required to distinguish between the interpretation of productivity as throughput efficiency, and productivity as indicator for knowledge assets.

Our results implicitly show that the standard knowledge-capital model of FDI has a substantial blind spot by overlooking the large role of the macroeconomic preconditions for the private knowledge-creation efforts of firms. The public knowledge-creation efforts and the presence of national knowledge-throughput efficiency appear to have a large role in explaining the outward FDI performance of countries. Our results can be interpreted as indicating that private firms derive bounteous positive externalities from universities and (semi-)public institutions that freely create and disseminate knowledge assets. Firms do contribute to financing of research projects in universities and other institutions of higher education, but the score of the BFIN_HERD indicator in Table 5 indicates that such finance has not a significant impact for explaining the international pattern of outward FDI.

The importance of data normalisation. In Section 2 discussed the impact of data normalisation, in the form of intensive-margin indicators for the relative abundance of a country's knowledge assets. We illustrate this by applying the same rank correlation approach between GDP per unit of GDP (OUTST_GDP) and 25 extensive-margin indicators of knowledge creation. The latter are uncorrected for the effects of economic scale on knowledge-creation activities. The 25 extensive-margin indicators cover the same knowledge-creation domains as in Table 5. Because of the heteroskedasticity effects, both the OUTST_GDP variable and the extensive-margin indicators are expressed in logs, before determining county rankings. The results are shown in Tables 6a and 6b.

A first remarkable difference with the results of Table 5a is that many *tau-b* correlation coefficients are quite low now, while many indicators appear to have no statistically significant impact on explaining the ranking for outward FDI. And in four cases, even the sign of the rank correlation is negative. By knowledge domain, the table shows that all input-related knowledge indicators score very weak in comparison to Table 5a, while output-related indicators score more strongly. This suggests that the output-related knowledge indicators follow the scale effects in the data. Table 6a summarises the implications for the tested model predictions. Overall we see lower support scores for the three

[30] Battisti *et al*., 2021; Mataloni, 2011; Bernard *et al*., 2013; Wagner, 2012; Girma *et al*., 2005.

Table 6a Rank correlation between outward FDI stocks per unit of GDP (OUTST_GDP) and extensive-margin indicator, grouped by knowledge domain (full country sample)

Knowledge system component	Indicator name[#)]	No. of compared country observations	Rank correlation, Kendall's *tau-b*	Prob>|z|	Confidence code [&)]
(Re-)activation of existing public knowledge	HERD_S	42	0.194	0.072	*
	HRES_S	37	–0.012	0.927	
	HPER_S	40	0.072	0.522	
	HFTE_S	40	0.087	0.435	
	FEMRES_S	36	0.025	0.838	
Creating of new public knowledge: input-related indicators	GERD_S	42	0.189	0.079	*
	GOVERD_S	42	0.011	0.931	
	TOTRES_S	37	0.048	0.685	
	GVRES_S	37	–0.132	0.255	
	TOTPER_S	38	0.073	0.530	
	GVPER_S	39	–0.107	0.345	
	TOTFTE_S	39	0.082	0.468	
	GVFTE_S	39	–0.128	0.256	
New public knowledge: output-related indicators	PAT_R_S	129	0.241	0.000	***
	JRNART_S	160	0.274	0.000	***
Acquisition of foreign knowledge assets	PAT_NR_S	136	0.222	0.000	***
Input-related indicators for knowledge-creation efforts by private business	BERD_S	42	0.227	0.036	**
	BRES_S	38	0.141	0.218	
	BPER_S	41	0.129	0.238	
	BFTE_S	40	0.151	0.173	
Output-related indicators for knowledge-creation efforts by private business	PCTPAT_S	42	0.308	0.004	***
	ICTPAT_S	42	0.329	0.002	***
	BIOPAT_S	42	0.368	0.000	***
	TMDRES_S	130	0.210	0.000	***
	TM_TOT_S	136	0.197	0.001	***

Legend: [#)] For description of the extensive-margin indicators, see Annex III, and for the source of the original indicators, see Annex I. [&)] Coding of confidence levels: *** p<0.01, ** p<0.05, * p<0.10.

model predictions. Two-thirds of the firm-related knowledge-creation indicators (mostly related to patenting and trademarks) have a significant and positive impact on outward FDI. This finding could capture the fact that multinational firms are generally larger than the average domestic firm. Table 6a also shows that only 44% of the relevant indicators for public knowledge-creation have a significant and positive impact on outward FDI. This mostly relates to universities and higher education, total R&D budgets, and scientific publication activities; scale matters in all of these areas.

Table 6b Overall indicator count statistics with regard to model predictions when extensive-margin indicators are used (full country sample)

Model predictions	Overall count statistics §)
1. Firm-specific knowledge assets (G_{fit}) should have a significant and positive impact on a country's outward FDI volume (zero hypothesis)	6 of 9 indicators (66.7%)
2. Public knowledge inputs (M_{pit}) into firm-level proprietary knowledge assets should have a significant and positive impact on a country's outward FDI volume.	7 of 16 indicators (43.8%)
3. Most individual indicators for a country's 'relative abundance of knowledge capital' should have a positive and statistically significant impact on outward FDI volume.	13 of 25 indicators (52.0%)

Legend: §) The score reflects the number of rank correlation indicators (Kendall *tau-b*) that comply with the condition in the first column by being statistically significant and having the predicted sign. The numbers in brackets gives the share of the total number of indicators that is relevant for that particular rank correlation. Source: Table 5a

Comparing all extensive-margin results with the intensive-margin results of Tables 5a and 5b, it turns out to be very important that the knowledge-development indicators are normalised and de-scaled for a meaningful inter-country comparison of the relative abundance of knowledge assets.

IV. Robustness tests

The rest of the paper investigates the stability and robustness of the findings reported in Tables 5a and 5b. The first test is about a possible bias due to tax-motivated FDI, which might inflate the outward FDI performance of tax paradises and tax-sheltering countries. The second robustness test is to drop the normalisation of the dependent FDI variable, going from outward FDI stocks per unit of GDP (OUTST_GDP) to total outward FDI stock as basis for the country ranking. The third robustness applies two shocks to the country sample to test the stability of the outcomes.

Biased FDI data due to tax routing of FDI? The FDI data that we used are based on immediate partner countries. However, there is ample evidence that FDI patterns may be driven by tax motives.[31] The test is that we remove the countries with proven policy reputations as tax paradises and facilitators of tax-sheltering and tax avoiding. If our results are biased due to tax routing, then it should make a difference when we remove such countries from our dataset, redo the country ranking, and redo the rank correlation test. This test implies that the average number of country observations per indicator falls.[32]

[31] UNCTAD, 2022; Beer *et al.*, 2020; Keen *et al.*, 2022; Damgaard *et al.*, 2019.

[32] The average number of compared country observations dropped to 102 (was 110), with the minimum and maximum being, respectively, 32 (was 34) and 156 (was 171).

In total, we identified 18 countries and geographical entities:[33] Netherlands Antilles, American Samoa, Bahamas, Bermuda, Switzerland, Cayman Islands, Cyprus, Iceland, Liberia, Luxembourg, Marshall Islands, Malta, Mauritius, The Netherlands, Panama, Seychelles, British Virgin Islands, and US Virgin Islands. For the remaining countries, this robustness check had only a small impact. The full table with detailed results is provided as Table AIII.1 in the Online Annex. Compared to the summary results of Table 5b, the support for the four model predictions becomes, respectively, 67% (was 60%), 86% (was 93%), 80% (was 82%), and 100% (was 100%). So, it is fair to say that the explanatory power of the knowledge-capital theory of FDI is hardly affected by tax routing practices in outward FDI.

Changing the specification of the dependent FDI variable. The next set of robustness tests uses the total value of outward FDI stocks for each country rather than OUTST_GDP (ratio of outward FDI stocks over GDP). Countries are now ranked by their mean annual outward FDI stocks in the period 2000-2020, and this ranking is compared with the country ranking for each intensive-margin indicator for their knowledge system. The indicators for the intensive and extensive margin of knowledge creation remain unchanged. To compensate for dropping the normalization of FDI, we add the rank correlation between each knowledge indicator and national GDP as a control variable. This allows to check whether a particular indicator correlates stronger with outward FDI than with domestic GDP. This control variable checks for the dominance of scale-related impacts (as in Table 6b). The detailed results for this robustness check are given in the Online Annex (Table AIII.2). Table 7 summarises the results with respect to the four model-based predictions plus the added control variable.

Overall we find that Table 7 reports similar results as those in Table 5. This shows that the pattern is robust to a different specification of the dependent variable. We discuss the results by knowledge domain. Most indicators for firm-based knowledge-creation are positively correlated with outward FDI. While BFIN_HERD (percentage of higher-education expenditures on R&D that is financed by the business sector) still had no significant positive impact, the average *tau-b* score of the other three business indicators is 0.356 and significant. The 23 indicators for public knowledge creation and reactivation are in most cases significant and positively correlated with outward FDI. In eleven cases, the *tau-b* for these indicators are higher than the 0.356 average for the three business-related indicators.[34] The indicators for national productivity and knowledge-throughput efficiency have a strong positive correlation with outward FDI, with an average *tau-b* of 0.392. The last category of intensive-margin indicators measures how firms use knowledge-creation inputs as proprietary assets.

[33] A simple tool to identify most of such countries is to look at the ratio of outward (or inward) FDI stocks over total domestic firm-related investment stocks (calculated in in national accounts as total investment minus government investment and minus housing investment).The median of this ratio for outward FDI stocks for 205 countries in the period 2005-2019 was 0.146. Countries below the median level can be regarded as tax neutral. By adding weights for the size of domestic firm-related investment, one may also identify larger tax-sheltering countries like Netherlands, Switzerland or Ireland that themselves may easily attract substantial 'real' (not tax-related) FDI stocks.

[34] A few negative results are remarkable, but we do not delve into speculation about the interpretation of these. The FEM_RESR indicator (Women as % of total researchers) has a significantly negative correlation with outward FDI. And GVE_XGDP (Expenditure on in-house governmental R&D) appears not to have any significant impact on outward FDI.

Table 7 Rank correlation between total outward FDI and intensive-margin indicators, abbreviated results (full country sample)

Model predictions	Overall count statistics §)
1. Firm-specific knowledge assets (G_{fit}) should have a significant and positive impact on a country's outward FDI volume (zero hypothesis)	11 of 15 indicators (73.3%)
2. Public knowledge inputs (M_{pit}) into firm-level proprietary knowledge assets should have a significant and positive impact on a country's outward FDI volume	26 of 29 indicators (89.7%)
3. Most individual indicators for a country's 'relative abundance of knowledge capital' should have a positive and statistically significant impact on outward FDI volume	37 of 44 indicators (84.1%)
4. National knowledge-throughput efficiency (v_{it}) should have a positive and significant impact on a country's outward FDI	8 of 8 indicators (100%)
5. The positive and significant correlation of intensive-margin indicators with outward FDI is stronger than their correlation with GDP (related to prediction 3)	41 of 52 indicators (79 %)

Legend: §) The score reflects the number of rank correlation indicators (Kendall *tau-b*) that comply with the condition in the first column by being statistically significant and having the predicted sign. Source: Online Annex, Table AIII.2.

Most items appear to be strongly correlated with outward FDI, but this does not hold for trade-mark registrations. The last row of Table 7 gives the correlation of the intensive-margin indicators with the home country's GDP. As was to be expected, many indicators are significantly and positively correlated with GDP. This shows the relevance of the earlier de-scaling operation. However, for 41out of 52 indicators, their positive rank correlation with outward FDI is stronger than their rank correlation with domestic GDP. This control variable thus supports the third model prediction of Section I.

Shocking the country samples. Three tests are done to shake-up the country sample. We keep total outward FDI as the dependent variable. The first shock is to restrict the sample to countries which had non-zero inward and outward FDI during all years over the period 2000-2020. This removes a number of small countries and island states, which had erratic annual patterns in reported FDI stocks. Reducing of the country sample to those with all-time FDI lowers the number of compared country observations per indicator to an average of 77 (was 110 in Table 5a), with the minimum and maximum being, respectively, 34 (was 36) and 126 (was 171). The second shock removes countries from the sample that have a proven reputation for having policies that facilitate tax routing of FDI (similar to the first robustness test of this Section), which lowers the number of country observations to an average of 98. The third shock is the toughest one, it combines the filtering criteria of the first two shocks, thereby reducing the average number of country observations per indicator to 71. It should be stressed that this test is more or less random, because the first country filter (only all-time-FDI countries) is not at all needed for achieving reliable outcomes. Table 8 summarizes the results of the three sample-shocking tests with reference to the four model predictions.

The differences are small, so the results are stable across the four country samples. The share of the intensive-margin indicators for firm-based knowledge creation remains in the 67-73% range. The support for the role of public knowledge-creation is even higher, namely in the 86-90% range. The share of indicators that are correlated stronger with outward FDI than with domestic GDP remains in

the 75-79% range. The average share of all intensive-margin knowledge-creation indicators that have a significant and positive rank correlation with outward FDI is steady in the 82-84% range, which again confirms the strong support for the knowledge-capital theory of outward FDI.

Table 8 Comparing rank correlation between total outward FDI and intensive-margin indicators for four different country samples

Summary statistics in terms of the model predictions	Full country sample (Table 7)	Only countries with all-time outward FDI stocks	Full country sample, minus countries with tax evasion / tax-sheltering policies	Countries with all-time outward FDI stocks, no tax evasion / tax-sheltering countries
1. Firm-specific knowledge assets (G_{fit}) should have a significant and positive impact on a country's outward FDI volume (zero hypothesis)	73%	67%	73%	73%
2. Public knowledge inputs (M_{pit}) into firm-level proprietary knowledge assets should have a significant and positive impact on a country's outward FDI	90%	90%	86%	86%
3. Most individual indicators for a country's 'relative abundance of knowledge capital' should have a positive and statistically significant impact on outward FDI volume	84%	82%	82%	82%
4. National knowledge-throughput efficiency (v_{it}) should have a positive and significant impact on a country's outward FDI	100%	100%	100%	100%
5. The positive and significant correlation of intensive-margin indicators with outward FDI is stronger than their correlation with GDP	79%	77%	75%	79%

Legend: The score reflects the number of rank correlation indicators (Kendall *tau-b*) that comply with the condition in the first column by being statistically significant and having the predicted sign. Source: Online Annex Tables AIII.2 and AIII.4.

V. Summary and conclusions

The knowledge-capital model of outward FDI by Markusen (and some other authors) provides a plausible theory for explaining international patterns of bilateral FDI stocks. Its basic tenet is that firms own proprietary knowledge assets that can be applied outside the home-country location and that are non-rival in their use. Such knowledge capital assets form a source of firm-level scale effects. Their use outside the home country raises the returns to such assets. The model has been widely applied in

the business studies and international economics literature. However, as far as we know, there has never been an empirical test of an important implication of this theory: *if the knowledge-capital theory of foreign direct investment is correct, countries with relatively large outward FDI stocks should also have a relative abundance of firm-specific knowledge assets*. This paper presents the first empirical test of the knowledge-capital theory of outward FDI that effectively uses the inter-country variation in knowledge-capital assets. Given the lack of reliable and comparable data for each country's 'abundance of proprietary knowledge assets', our paper designs and applies a new way to investigate this matter. It uses the fact that multinational firms are embedded in the knowledge system of their origin countries. These firms use, apply and encapsulate knowledge inputs from their home country's public knowledge-creation system. And because there are more and better data on public knowledge-system performance of countries, this could also form a key source of information on a country's proprietary knowledge assets. To explore this idea, the paper complements the knowledge-capital model with a new module that formalizes the interaction between the knowledge creation of firms and the public knowledge development of countries. Firms encapsulate new public knowledge; they mix it with internal knowhow and commercial expertise into proprietary assets. The predictions from this model yield a set of four testable hypotheses, and none of them could be rejected.

We created a database with almost 80 empirical indicators that quantify the most important aspects of national knowledge-creation efforts, covering 209 countries over the period 2000-2020. With regard to the knowledge-capital model of outward FDI, the empirical test found robust evidence that firm-specific knowledge assets have a significant and positive impact on a country's outward FDI volume. More than 80% of the indicators for a country's 'relative abundance of knowledge capital' had a positive correlation with outward FDI, and their correlation with outward FDI was stronger than with domestic GDP. Two model prediction dealt specifically with our extension of the of Markusen's knowledge-capital theory; both predictions were confirmed by the empirical results. We found strong evidence that public knowledge inputs (into firm-level proprietary knowledge assets) have a significant and positive impact on outward FDI, even stronger than holds for the firm-based knowledge inputs. Furthermore, national performance with respect to productivity and domestic knowledge-throughput efficiency (eight different indicators) strongly correlates with a country's outward FDI performance. The outcomes were stable and robust. They held for different sub-samples of the full country set (about 200) and it did not matter whether FDI was measured in nominal value or in relative terms (outward FDI per unit of GDP).

The empirical results show that the knowledge-capital model is correct, but also that it has a substantial blind spot by overlooking the large role of domestic knowledge-system preconditions for the private knowledge-creation efforts of firms. The public knowledge-creation efforts and national knowledge-throughput efficiency appear to have a large role in explaining the outward FDI performance of countries. Our results suggest that private firms derive bounteous positive externalities from universities and (semi-) public institutions that freely create and disseminate knowledge assets. The picture that large firms are the main innovating force in an economy should be re-evaluated.

The results also have a value for policy. Our evidence shows that governments should not be too timid in negotiations with domestic or foreign multinational firms that want to share in the results of national

knowledge-creating efforts. It seems fair that governments are in a good position to negotiate certain performance guarantees (e.g. with respect to employment or investment) in exchange.

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***Online Annex*:** The detailed results per indicator (separate for different country samples) are available in an online annex (cf. *Kox_Extended_KC_model_ONLINE_ ANNEX.pdf*).

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ANNEX I TIME DYNAMICS OF NATIONAL KNOWLEDGE STOCKS

Proof of Proposition 1

If behavioural parameters described in Table 1 (β_i, ε_i, φ_i, ψ_i and δ_i) are time-invariant, the proof of Proposition 1 (time dynamics of public knowledge stocks) is as follows. Old vintages of public knowledge stocks are fully discarded after N years ($M_{io,t-N} = 0$). Vintages from younger annual cohorts ($\theta < N$) are depreciated by δ_i, hence:

(A1) $M_{io,t-\theta} = (1 - \delta_i)\, M_{io,t-(\theta-1)} \qquad \forall\, \theta < N$

From Table 1 we further have:

(A2) $M_{piit} = v_i\, \beta_i\, Y_{it}$ (A3) $M_{fRit} = v_i\, \varphi_i\, Y_{it}$ (A4) $M_{pRit} = v_i\, \psi_i\, Y_{it}$

(A5) $\Delta M_{pit} = v_i\ (\beta_i + \varphi_i + \psi_i)\ Y_{it}$

(A6) $M_{pit} = \Delta M_{pit} + \varepsilon_i\ M_{io,t}$

Suppose that the build-up of public knowledge stocks starts in year $t - N$, so that $M_{io,t-N} = 0$, and equation (A6) reduces to: $M_{pi,t-N} = \Delta M_{pi,t-N}$, and that same $\Delta M_{pi,t-N}$ will become the first old vintage knowledge stock that has to be re-activated like in (A6) and depreciated like in (A1) at the end of the next year $t - (N - 1)$, so that:

(A7) $M_{pi,t-(N-1)} = \Delta M_{pi,t-(N-1)} + \varepsilon_i\ (1 - \delta_i)\ \Delta M_{pi,t-N}$

Because of (A5) that gives:

(A8) $M_{pi,t-(N-1)} = v_i\ (\beta_i + \varphi_i + \psi_i)\ Y_{i,t-(N-1)} + \varepsilon_i\ (1 - \delta_i)\ v_i\ (\beta_i + \varphi_i + \psi_i)\ Y_{i,t-N}$

$= v_i\ (\beta_i + \varphi_i + \psi_i)\ \left[Y_{i,t-(N-1)} + \varepsilon_i\ (1 - \delta_i)\ Y_{i,t-N}\right]$

$= v_i\ (\beta_i + \varphi_i + \psi_i)\ Y_{i,t-(N-1)}\ \left[1 + \varepsilon_i\ (1 - \delta_i)\ \frac{Y_{i,t-N}}{Y_{i,t-(N-1)}}\right]$

If we define $X_{Y,t-(N-1)} = \frac{Y_{i,t-N}}{Y_{i,t-(N-1)}}$ as the chain index of GDP, we get:

(A9) $M_{pi,t-(N-1)} = v_i\ (\beta_i + \varphi_i + \psi_i)\ Y_{i,t-(N-1)}\ \left[1 + \varepsilon_i\ (1 - \delta_i)\ X_{Y,t-(N-1)}\right]$

And because this same pattern repeats itself for all later vintages of old public knowledge assets, we may generalize the pattern for all years, thus obtaining:

(A10) $M_{pi,t} = v_i\ (\beta_i + \varphi_i + \psi_i)\ .\left[1 + \varepsilon_i\ (1 - \delta_i)\ X_{Y,t}\right].\ Y_{i,t}$ QED ■

Proof of Proposition 2

If behavioural parameters described in Table 2 (α_{is}, ε_{is}, ω_{is}) and firm-level depreciation parameter δ_{is} are time-invariant, we prove Proposition 2 (time dynamics of proprietary knowledge stocks of firms in country *i*). Old vintages of proprietary private knowledge assets are fully discarded after N years ($G_{iso,t-N} = 0$). Stocks from younger annual knowledge cohorts ($\theta < N$) are depreciated by δ_{is}:

(A11) $G_{iso,t-\theta} = (1 - \delta_{is})\ G_{iso,t-(\theta-1)}$ $\forall\ \theta < N\ ;\ \forall\ s$

From Table 2 we further have:

(A12) $G_{sit} = v_i\ z_s\ \alpha_{is}\ Y_{it}$ $\forall\ s$

(A13) $G_{spit} = v_i\ z_s\ \omega_{is}\ \left(M_{pi,t-1}\right)\ Y_{it}$ $\forall\ s$

so that annual new proprietary knowledge of all firms amounts to:

(A14) $\Delta G_{fit} = \sum_s v_i\ z_s Y_{it}\ \left[\alpha_{is} + \omega_{is}\ \left(M_{pi,t-1}\right)\right]$

Re-activated older proprietary knowledge assets are the result of the following sub-process:

(A15) $G_{isot} = \sum_s v_i\ z_s\ \varepsilon_{is}\ (G_{iso})\ Y_{it}$

Suppose that in year $t-N$ the knowledge stock of firms starts to build up. There are no old vintages of proprietary knowledge stocks yet ($G_{iso,t-N}=0$) and total knowledge stocks at the end of the first year amount to:[35]

(A16) $$G_{fi,t-N}=\Delta G_{fi,t-N}=\sum_s v_i\, z_s\, Y_{i,t-N}\left[\,\alpha_{is}+\omega_{is}\left(M_{pi,t-N-1}\right)\right]$$

That same $\Delta G_{fi,t-N}$ will become the first old vintage of proprietary knowledge that has to be re-activated like in (A15) and depreciated like in (A11) at the end of the next year $t-(N-1)$, so that:

(A17) $$G_{fi,t-(N-1)}=\Delta G_{fi,t-(N-1)}\;+\;\sum_s \varepsilon_{is}\,(1-\delta_{is})\{\Delta G_{fi,t-N}\}$$

After some substitutions, this becomes:

(A18) $$G_{fi,t-(N-1)}=v_i\,\sum z_s\left[\,\alpha_{is}+\omega_{is}\left(M_{pi,t-N-1}\right)\right]Y_{i,t-(N-1)}\left\{1+\varepsilon_{is}\,(1-\delta_{is})\frac{Y_{i,t-N}}{Y_{i,t-(N-1)}}\right\}$$

If we define $X_{Y,t-(N-1)}=\frac{Y_{i,t-N}}{Y_{i,t-(N-1)}}$ as the chain index of GDP, we get:

(A19) $$G_{fi,t-(N-1)}=v_i\,\sum z_s\left[\,\alpha_{is}+\omega_{is}\left(M_{pi,t-N-1}\right)\right]Y_{i,t-(N-1)}\left\{1+\varepsilon_{is}\,(1-\delta_{is})\,X_{Y,t-(N-1)}\right\}$$

And because this same pattern repeats itself for all later vintages of old proprietary knowledge assets of firms, we may generalize the pattern for all years, thus obtaining:[36]

(A20) $$G_{fi,t}=v_i\,\sum z_s\left[\,\alpha_{is}+\omega_{is}\left(M_{pi,t-1}\right)\right].\left\{1+\varepsilon_{is}\,(1-\delta_{is})\,X_{Y,t}\right\}.Y_{i,t}$$

Finally, using Proposition 1, $M_{pi,t-1}$ can be substituted into (A20):

(A21) $$G_{fi,t}=v_i\,Y_{i,t}\,\sum_s z_s\,A_{is}\left[\,\alpha_{is}+\omega_{is}(\beta_i+\varphi_i+\psi_i)\,A_i\,v_i\,Y_{i,t-1}\right]$$

with $A_{is}\equiv\left\{1+\varepsilon_{is}\,(1-\delta_{is})\,X_{Y,t}\right\}$ and $A_i\equiv\left\{1+\varepsilon_i\,(1-\delta_i)\,X_{Y,t}\right\}$

QED ■

[35] Because $M_{pi,t-N-1}$ is an independent process, we assume that $M_{pi,t-N-1}$ does already exist;

[36] Note that the structure is the same as (A10) in the proof of Proposition 1.

Annex II Description of national knowledge-capital variables, and their original sources

Indicator	Description	Source + codename in original source
Intensive knowledge-creation margin		
ADEDU_F	Female with advanced education, as % of female working-age population	WDI (SL_TLF_ADVN_FEZS)
ADEDU_M	Male with advanced education, as % of male working-age population	WDI (SL_TLF_ADVN_MAZS)
LQ_CONTR	Contribution of labour quality to GDP growth (growth accounting)	TED (LQ_contr)
FEM_RESR	Women researchers as % of total researchers	MSTI (TH_WRXRS)
TOT_RESR	Researchers in R&D (per million people)	WDI (SP_POP_SCIE_RDP6)
TOT_TECH	Technicians in R&D (per million people)	WDI (SP_POP_TECHRDP6)
GII_MAIN	Mean score for Global Innovation Indexes 2011-2020, normalized by GDP in PPP$ 2019	WIPO (GII)
GII_INPUT	Global Innovation subindex for inputs 2020, normalized by GDP in PPP$ 2019	WIPO (GII inputs subindex)
GERCGDP	Research and development expenditure (% of GDP, curr. prices, USD)	MSTI (GB_XPDRSDVGD_ZS)
GERPGDP	Gross domestic expenditure on R&D (GERD) as % of curr. GDP (PPP$)	MSTI (G_XGDP)
GERD_CAP	Gross domestic expenditure on R&D (in PPP$), per capita of population	WDI (G_XPOP)
GVE_XGDP	Governm. intramural expenditure on R&D (GOVERD) as % of curr. GDP (PPP$)	MSTI (GV_XGDP)
HED_XGDP	Higher-education expenditure on R&D (HERD) as % of current GDP (PPP$)	MSTI (H_XGDP)
ALLRES_LF	Total researchers per thousand of domestic labour force	MSTI (TP_RSXLF)
RDPERS_LF	Total R&D personnel (incl. staff), per thousand of domestic labour force	MSTI (TP_TTXLF)
ALLRES_EM	Total researchers per thousand of domestic total employment	MSTI (TP_RSXEM)
RDPERS_EM	Total R&D personnel (incl. staff), per thousand of dom. total employment	MSTI (TP_TTXEM)
GII_OUTPUT	Global Innovation subindex for outputs 2020, normalized by GDP in PPP$ 2019	WIPO (GII output subindex)
ECONPAP	Number of papers in economics, normalized by size of domestic GDP	REPEC (r_econpap_n1)
JRN_ART	Number of articles in scientific journals, normalized by size of domestic GDP	WDI (IP_JRN_ARTC_SC)
JUDINDEP	Judicial independence of government, mean score 2000-2019	FRASER (judicialindep)
IMPART_C	Impartiality of legal courts, mean score 2000-2019	FRASER (impartcourt)
IMP_PUBL	Impartiality of public administration, mean score 2000-2019	FRASER (impartpubad)
PROTPROP	Protection of property rights, mean score 2000-2019	FRASER (protpropr)
LEG_FORCE	Effectiveness legal enforcement, mean score 2000-2019	FRASER (legalenforc)
INFDI_GDP	Total inward FDI stocks, normalized by size of domestic GDP	UNCTAD (inst_gdp)

BF_IMSRV	import of business and financial services, as % of total services import	KVL (ocs_impsh_n4)
KIBS_IMSRV	import of knowledge- intensive business services, as % of total services import	KVL (kibs_impsh_n4)
PAT_NRES	Number of patent applications by non-residents, normalized by GDP	WDI (IP_PAT_NRES_n1)
INT_USER	Individuals using the Internet, as % of population	WDI (IT_NET_USER_ZS)
INTSECUR	Number of secure Internet servers, per million people	WDI (IT_NET_SECR_P6)
BBND_SUB	Number of fixed broadband subscriptions, per million people	WDI (IT_NET_BBND_P2)
ICT_CONTR	Contribution of ICT assets to GDP growth (growth accounting)	TED (ICT_contr)
LP_EMPL	Labour productivity p. person employed, converted to 2020 PPP$	TED (LP_eksL)
LP_HOUR	Labour productivity p. hour worked, converted to 2020 PPP$	TED (LP_eksH)
FORGN_MV	Freedom of foreigners to visit, mean score 2000-2019	FRASER (forgn_move)
STARTABUS	Freedom to setup up a business, mean score 2000-2019	FRASER (startabus)
BERD_GDP	Total business expenditure on R&D (BERD) as % of current GDP (PPP$)	MSTI (B_XGDP)
BUX_GERD	% of GERD that is performed by the business enterprise sector	MSTI (G_XEB)
BFIN_HERD	% of higher-education expend. on R&D that is financed by the business sector	MSTI (H_XFB)
BRES_TOT	Total business enterprise R&D personnel as a percentage of national total	MSTI (BP_TTXTT)
HT_MFGEX	High-technology exports, as % of total manufacturing exports	WDI (TX_VAL_TECHMF_ZS)
IT_SERVEX	Exports of ICT services, as % of total services exports	WDI (BX_GSR_CCIS_ZS)
ITPROD_EX	Exports of ICT goods, as % of total merchandise exports	WDI (TX_VAL_ICTG_ZS_UN)
BF_SRVEX	Export of business and financial services, as % of total services export	KVL (ocs_expsh_n4)
KBS_SRVEX	Export of knowledge-intensive business services, as % of total services export	KVL (kibs_expsh_n4)
PATP_GDP	No. of patents filed under the PCT (priority yr), per 1000 ppp$ of GDP	MSTI (P_PCT_n1)
PATI_GDP	No. of ICT patents filed under the PCT (priority yr), per 1000 ppp$ of GDP	MSTI (P_ICTPCT_n1)
PATB_GDP	No. of biotech patents filed under the PCT (priority yr), per 1000 ppp$ of GDP	MSTI (P_BIOPCT_n1)

Extensive knowledge-creation margin

HERD_S	Log of higher-education expenditure on R&D (curr. PPP$)	MSTI (H_PPP_s)
HRES_S	Log of total no. of researchers in higher-education sector (headcount)	MSTI (HH_RS_s)
HPER_S	Log of total number of higher-education R&D personnel, incl. staff (headcount)	MSTI (HP_TT_s)
HFTE_S	Log of total number of national researchers in higher-education sector (FTE)	MSTI (HP_RS_s)
FEMRES_S	Log of total number of female researchers (headcount)	MSTI (TH_WRS_s)
GII_MAIN_S	log of Global Innovation Index 2020 (not normalized for economic scale)	WIPO (GII)

GII_INPT_S	log of Global Innovation Inputs subindex 2020 (not normalized for econ. scale)	WIPO (GII inputs)
GERD_S	Log of gross domestic expenditure on R&D (curr. PPP$)	MSTI (G_PPP_s)
GOVERD_S	Log of governm. intramural expenditure on R&D (curr. PPP$)	MSTI (GV_PPP_s)
TOTRES_S	Log of total number of researchers (headcount)	MSTI (TH_RS_s)
GVRES_S	Log of total number of researchers in government sector (headcount)	MSTI (GH_RS_s)
TOTPER_S	Log of total number of R&D personnel, incl. staff (headcount)	MSTI (TP_TT_s)
GVPER_S	Log of total number of governm. sector R&D personnel, incl. staff (headcount)	MSTI d (GP_TT_s)
TOTFTE_S	Log of total number of national researchers (FTE)	MSTI (TP_RS_s)
GVFTE_S	Log of total number of national researchers in government sector (FTE)	MSTI (GP_RS_s)
GII_OUTP_S	log of Global Innov. Outputs subindex 2020 (not normalized for econ. scale)	WIPO (GII inputs)
PAT_R_S	Log of number of patent applications by residents	WDI (IP_PAT_RESD_s)
JRNART_S	Log of number of articles in scientific journals	WDI (IP_JRN_ARTC_SC_s)
PAT_NR_S	Log of number of patent applications by non-residents	WDI (IP_PAT_NRES_s)
BERD_S	Log of total business expenditure on R&D (curr. PPP$)	MSTI (B_PPP_s)
BRES_S	Log of total number of researchers in busin. enterprise sector (headcount)	MSTI (BH_RS_s)
BPER_S	Log of total number of busin. sector R&D personnel, incl. staff (headcount)	MSTI (BP_TT_s)
BFTE_S	Log of total number of national researchers in business sector (FTE)	MSTI (BP_RS_s)
PCTPAT_S	Log of no. of patents filed under the PCT (priority year)	MSTI (P_PCT_s)
ICTPAT_S	Log of no. of ICT patents filed under the PCT (priority year)	MSTI (P_ICTPCT_s)

Legends: FRASER: Economic Freedom of the World (Gwartney *et al*, 2021). KVL: World Services Trade Matrix (KVL Economic Policy Research). MSTI: Main Science and Technology database (OECD). TED: The Conference Board Total Economy Database™ (The Conference Board, De Vries, 2022). UNCTAD: World Investment Report 2021. WDI: World Development Indicators (World Bank). WIPO: The Global Innovation Index 2020 (Dutta *et al.* 2020)

Annex III Extensive-margin indicators of national knowledge creation: Scale-based indicators

National knowledge system	Variable description	Variable name
(Re-)activation of existing public knowledge	Log of higher-education expenditure on R&D (curr. PPP$)	HERD_S
	Log of total no. of researchers in higher-education sector (headcount)	HRES_S
	Log of total number of higher-education R&D personnel, incl. staff headcount)	HPER_S
	Log of total number of national researchers in higher-education sector (FTE)	HFTE_S
	Log of total number of female researchers (headcount)	FEMRES_S
Creating of new public knowledge: input indicators	Log of gross domestic expenditure on R&D (curr. PPP$)	GERD_S
	Log of governm. intramural expenditure on R&D (curr. PPP$)	GOVERD_S
	Log of total number of researchers (headcount)	TOTRES_S
	Log of total number of researchers in government sector (headcount)	GVRES_S
	Log of total number of R&D personnel, incl. staff (headcount)	TOTPER_S
	Log of total number of governm. sector R&D personnel, incl. staff (headcount)	GVPER_S
	Log of total number of national researchers (FTE)	TOTFTE_S
	Log of total number of national researchers in government sector (FTE)	GVFTE_S
Creating of new public knowledge: output indicators	Log of number of patent applications by residents	PAT_R_S
	Log of number of articles in scientific journals	JRNART_S
Acquisition of foreign knowledge	Log of number of patent applications by non-residents	PAT_NR_S
Business research and knowledge-creation efforts	Log of total number of national researchers in business sector (FTE)	BFTE_S
	Log of total business expenditure on R&D (curr. PPP$)	BERD_S
	Log of total number of researchers in busin. enterprise sector (headcount)	BRES_S
	Log of total number of busin. sector R&D personnel, incl. staff (headcount)	BPER_S
Firms' absorbing of public knowledge inputs	Log of no. of patents filed under the PCT (priority year)	PCTPAT_S
	Log of no. of ICT patents filed under the PCT (priority year)	ICTPAT_S
	Log of no. of biotech patents filed under the PCT (priority year)	BIOPAT_S
	Log of number of trademark applications by direct residents	TMDRES_S
	Log of total number of trademark applications	TM_TOT_S
Note: Annex Table II provides details on the original sources of each indicator.		

FOR ONLINE PUBLICATION

Online Annex with supplementary material for the paper

" Testing an extended knowledge-capital model of FDI"

Henk L.M. Kox

DETAILED RANK CORRELATION RESULTS

Table AIII.1 Summary results for the rank correlation between outward FDI stocks per unit of GDP (OUTST_GDP) and intensive-margin indicators, after removing countries with tax-evasion and tax-sheltering policies from the sample %)

Knowledge system component	Indicator name	No. of compared country observations	Rank correlation, Kendall's *tau-b*	Prob>|z|	Confid-ence code &)
(Re-)activation of existing public knowledge	ADEDU_F	136	0.161	0.006	***
	ADEDU_M	136	0.090	0.120	
	LQ_CONTR	112	0.076	0.236	
	FEM_RESR	32	–0.250	0.046	**
	TOT_RESR	109	0.497	0.000	***
	TOT_TECH	98	0.454	0.000	***
Creating of new public knowledge: input-related indicators	GII_MAIN	125	0.516	0.000	***
	GII_INPUT	114	0.559	0.000	***
	GERCGDP	119	0.404	0.000	***
	GERPGDP	38	0.408	0.000	***
	GERD_CAP	38	0.482	0.000	***
	GVE_XGDP	38	0.044	0.706	
	HED_XGDP	38	0.408	0.000	***
	ALLRES_LF	35	0.489	0.000	***
	RDPERS_LF	34	0.455	0.000	***
	ALLRES_EM	35	0.492	0.000	***
	RDPERS_EM	34	0.480	0.000	***
Creating of new public knowledge: output-related indicators	GII_OUTPUT	113	0.452	0.000	***
	ECONPAP	134	0.416	0.000	***
	JRN_ART	149	0.194	0.001	***
	JUDINDEP	135	0.420	0.000	***
	IMPART_C	135	0.448	0.000	***
	IMP_PUBL	134	0.389	0.000	***
	PROTPROP	135	0.415	0.000	***
	LEG_FORCE	135	0.320	0.000	***
Acquisition of foreign knowledge assets	INFDI_GDP	156	0.212	0.000	***
	BF_IMSRV	123	0.153	0.012	**
	KIBS_IMSRV	146	0.164	0.003	***
	PAT_NRES	126	0.121	0.047	**
National productivity and knowledge-throughput efficiency	INT_USER	153	0.501	0.000	***
	INTSECUR	153	0.464	0.000	***
	BBND_SUB	153	0.456	0.000	***

	ICT_CONTR	110	0.203	0.002	***
	LP_EMPL	112	0.575	0.000	***
	LP_HOUR	112	0.562	0.000	***
	FORGN_MV	135	0.224	0.000	***
	STARTABUS	135	0.321	0.000	***
Private business research and knowledge-creation efforts	BERD_GDP	38	0.386	0.001	***
	BUX_GERD	38	0.289	0.011	**
	BFIN_HERD	38	0.072	0.530	
	BRES_TOT	34	0.355	0.003	***
Absorbing of knowledge inputs by private business	HT_MFGEX	145	0.301	0.000	***
	IT_SERVEX	149	-0.080	0.148	
	ITPROD_EX	148	0.292	0.000	***
	BF_SRVEX	120	0.305	0.000	***
	KBS_SRVEX	146	0.067	0.206	
	PATP_GDP	38	0.454	0.000	***
	PATI_GDP	38	0.539	0.000	***
	PATB_GDP	38	0.539	0.000	***
	PATP_RES	120	0.105	0.092	*
	TM_DRES	122	–0.103	0.094	*
	TM_TOT	128	–0.144	0.016	**

Overall count statistics with regard to model predictions:

1. Indicators for private, firm-specific knowledge assets have a significant and positive rank correlation with outward FDI (per unit of GDP)	10 of 15 indicators (66.7%)
2. Indicators for public knowledge assets have a significant and positive rank correlation with outward FDI (per unit of GDP)	25 of 29 indicators (86.2%)
3. Indicators for national knowledge assets have a significant and positive rank correlation with outward FDI (per unit of GDP)	35 of 44 indicators (79.5%)
4. National knowledge-throughput efficiency has a positive and significant impact on a country's outward FDI.	8 of 8 indicators (100%)

Note: [%)] In total, we dropped 18 countries and geographical entities from the full country sample (cf. Section IV in main text for criterion and details). [&)] Coding of confidence levels: *** p<0.01, ** p<0.05, * p<0.10.

Table AIII.2 Rank correlation of intensive-margin knowledge-capital indicators with (outward and inward) FDI stock and with GDP, 2000-2020 period, full country sample

Indicator name	No. of country observa-tions	Rank correlation with outward FDI		Rank correlation with inward FDI		PM: Kendall rank corr. (tau-b) with own GDP
		Spearman's rho	Kendall's tau-b	Spearman's rho	Kendall's tau-b	
ADEDU_F	175	0.152**	0.101**	0.157**	0.105**	0.042
ADEDU_M	175	0.157**	0.102**	0.153**	0.104**	0.106**
LQ_CONTR	128	0.322***	0.212***	0.352***	0.232***	0.213***
FEM_RESR	36	-0.540***	-0.384***	-0.441***	-0.305***	-0.232**
TOT_RESR	135	0.721***	0.517***	0.659***	0.457***	0.394***
TOT_TECH	121	0.669***	0.478***	0.603***	0.423***	0.345***
GII_MAIN	147	0.751***	0.552***	0.697***	0.504***	0.369***
GII_INPUT	131	0.794***	0.592***	0.731***	0.536***	0.404***
GERCGDP	149	0.642***	0.450***	0.621***	0.438***	0.399***
GERPGDP	42	0.514***	0.336***	0.248	0.164	0.196*
GERD_CAP	42	0.585***	0.375***	0.368**	0.231**	0.171**
GVE_XGDP	42	0.148	0.109	-0.003	0.006	0.108
HED_XGDP	42	0.368**	0.240**	0.237	0.157	0.106
ALLRES_LF	39	0.415***	0.236**	0.141	0.077	0.074
RDPERS_LF	38	0.481***	0.306***	0.179	0.115	0.112
ALLRES_EM	39	0.395**	0.223**	0.120	0.058	0.072
RDPERS_EM	38	0.493***	0.309***	0.194	0.118	0.115
GII_OUTPUT	130	0.749***	0.551***	0.729***	0.537***	0.399***
ECONPAP	164	0.762***	0.569***	0.822***	0.617***	0.545***
JRN_ART	195	0.464***	0.298***	0.478***	0.300***	0.279***
JUDINDEP	165	0.559***	0.390***	0.461***	0.316***	0.231***
IMPART_C	165	0.598***	0.420***	0.524***	0.365***	0.273***
IMP_PUBL	162	0.511***	0.356***	0.441***	0.307***	0.222***
PROTPROP	165	0.579***	0.407***	0.507***	0.351***	0.278***
LEG_FORCE	165	0.465***	0.329***	0.417***	0.290***	0.252***
INFDI_GDP	197	0.110	0.067	.	.	-0.138***
BF_IMSRV	157	0.296***	0.227***	0.307***	0.233***	0.200***
KIBS_IMSRV	193	0.489***	0.350***	0.539***	0.390***	0.312***
PAT_NRES	153	0.122	0.096*	0.121	0.092*	0.011
INT_USER	205	0.664***	0.472***	0.529***	0.365***	0.268***
INTSECUR	209	0.622***	0.441***	0.497***	0.348***	0.219***
BBND_SUB	204	0.633***	0.451***	0.516***	0.366***	0.248***
ICT_CONTR	126	0.255**	0.167***	0.316***	0.204***	0.115*
LP_EMPL	128	0.762***	0.566***	0.649***	0.468***	0.368***
LP_HOUR	128	0.769***	0.575***	0.658***	0.474***	0.373***
FORGN_MV	165	0.171**	0.117**	0.145*	0.102*	0.031
STARTABUS	165	0.498***	0.347***	0.450***	0.319***	0.222***
BERD_GDP	42	0.522***	0.340***	0.269*	0.182*	0.220**
BUX_GERD	42	0.434***	0.299***	0.153	0.182*	0.187*
BFIN_HERD	42	0.153	0.122	0.057	0.043	0.048
BRES_TOT	38	0.592***	0.428***	0.402**	0.300***	0.303***
HT_MFGEX	178	0.504***	0.348***	0.461***	0.323***	0.256***
IT_SERVEX	185	-0.027	-0.019	0.003	0.000	0.056
ITPROD_EX	185	0.396***	0.262***	0.370***	0.242***	0.170***
BF_SRVEX	162	0.537***	0.374***	0.474***	0.338***	0.263***
KBS_SRVEX	196	0.224***	0.149***	0.333***	0.225***	0.238***
PATP_GDP	42	0.600***	0.398***	0.385***	0.254**	0.213**
PATI_GDP	42	0.689***	0.489***	0.488***	0.354***	0.285***
PATB_GDP	42	0.626***	0.429***	0.426***	0.303***	0.201*
PATP_RES	145	0.265***	0.174***	0.297***	0.187***	0.175***
TM_DRES	150	0.115	0.064	0.169**	0.100*	0.073
TM_TOT	159	0.046	0.028	0.104	0.063	0.057

Table AIII.3 Rank correlation of extensive-margin knowledge-capital indicators with total FDI stock (outward and inward) and with GDP, 2000-2020 period, full country sample

Indicator name	No. of country observa-tions	Rank correlation with outward FDI		Rank correlation with inward FDI		PM: Kendall rank corr. (tau-b) with own GDP
		Spearman's rho	Kendall's tau-b	Spearman's rho	Kendall's tau-b	
HERD_S	42	0.805***	0.628***	0.792***	0.436***	0.677***
HRES_S	37	0.574***	0.402***	0.539***	0.402***	0.694***
HPER_S	40	0.697***	0.497***	0.675***	0.500***	0.779***
HFTE_S	40	0.693***	0.497***	0.661***	0.495***	0.744***
FEMRES_S	36	0.629***	0.460***	0.574***	0.438***	0.759***
GII_MAIN_S	147	0.751***	0.552***	0.698***	0.504***	0.369***
GII_INPT_S	131	0.794***	0.592***	0.730***	0.536***	0.403***
GERD_S	42	0.806***	0.624***	0.736***	0.559***	0.814***
GOVERD_S	42	0.607**	0.436***	0.570***	0.408***	0.677***
TOTRES_S	37	0.657***	0.487***	0.583***	0.438***	0.734***
GVRES_S	37	0.411**	0.282**	0.374**	0.270**	0.586***
TOTPER_S	38	0.709***	0.514***	0.647***	0.482***	0.787***
GVPER_S	39	0.440***	0.304***	0.407**	0.279**	0.606***
TOTFTE_S	39	0.730***	0.544***	0.666***	0.505***	0.776***
GVFTE_S	39	0.404**	0.282**	0.367**	0.247**	0.584***
GII_OUTP_S	130	0.749***	0.551***	0.729***	0.537***	0.399***
PAT_R_S	145	0.698***	0.514***	0.7690***	0.573***	0.639***
JRNART_S	195	0.803***	0.612***	0.866***	0.686***	0.756***
PAT_NR_S	153	0.720***	0.528***	0.765***	0.578***	0.632***
BERD_S	42	0.806***	0.619***	0.707***	0.540***	0.745***
BRES_S	38	0.748***	0.565***	0.758***	0.502***	0.727***
BPER_S	41	0.748***	0.561***	0.679***	0.510***	0.746***
BFTE_S	40	0.758***	0.569***	0.684***	0.505***	0.728***
PCTPAT_S	42	0.857***	0.677***	0.768***	0.584***	0.686***
ICTPAT_S	42	0.832***	0.642***	0.727***	0.568***	0.656***
BIOPAT_S	42	0.887***	0.728***	0.783***	0.617***	0.668***
TMDRES_S	159	0.765***	0.565***	0.844***	0.654***	0.757***
TM_TOT_S	159	0.760***	0.565***	0.841***	0.654***	0.757***

Table AIII.4 Rank correlation of intensive-margin knowledge-capital indicators with total FDI stock (outward and inward) and with GDP, 2000-2020 period, full country sample, but without tax-sheltering countries

Indicator namel	No. of country observa-tions	Rank correlation with outward FDI		Rank correlation with inward FDI		PM: Kendall rank corr. (tau-b) with own GDP
		Spearman's rho	Kendall's tau-b	Spearman's rho	Kendall's tau-b	
ADEDU_F	163	0.116	0.076	0.123	0.084	0.042
ADEDU_M	163	0.139*	0.090*	0.149*	0.101*	0.129**
LQ_CONTR	121	0.313***	0.209***	0.359***	0.240***	0.243***
FEM_RESR	32	-0.493***	-0.343***	-0.373***	-0.250**	-0.234*
TOT_RESR	125	0.716***	0.515***	0.661***	0.459***	0.415***
TOT_TECH	112	0.658***	0.467***	0.609***	0.423***	0.386***
GII_MAIN	138	0.741***	0.540***	0.704***	0.506***	0.400***
GII_INPUT	123	0.783***	0.581***	0.735***	0.536***	0.433***
GERCGDP	137	0.637***	0.449***	0.625***	0.443***	0.414***
GERPGDP	38	0.525***	0.346***	0.235	0.158	0.218*
GERD_CAP	38	0.599***	0.380***	0.358**	0.226**	0.218*
GVE_XGDP	38	0.212	0.158	0.015	0.021	0.155
HED_XGDP	38	0.386**	0.243**	0.250	0.164	0.110
ALLRES_LF	35	0.457***	0.261**	0.163	0.089	0.103
RDPERS_LF	34	0.500***	0.312***	0.169	0.102	0.159
ALLRES_EM	35	0.446***	0.250**	0.148	0.072	0.099
RDPERS_EM	34	0.518***	0.323***	0.194	0.112	0.169
GII_OUTPUT	122	0.729***	0.533***	0.727***	0.534***	0.433***
ECONPAP	157	0.752***	0.560***	0.818***	0.613***	0.548***
JRN_ART	183	0.471***	0.300***	0.486***	0.305***	0.281***
JUDINDEP	154	0.532***	0.369***	0.445***	0.305***	0.250***
IMPART_C	154	0.580***	0.420***	0.513***	0.354***	0.288***
IMP_PUBL	152	0.480***	0.333***	0.413***	0.289***	0.221***
PROTPROP	154	0.556***	0.389***	0.495***	0.342***	0.287***
LEG_FORCE	154	0.448***	0.320***	0.401***	0.280***	0.251***
INFDI_GDP	181	0.027	0.015	0.108	0.071	-0.136*
BF_IMSRV	141	0.307***	0.231***	0.333***	0.247***	0.238***
KIBS_IMSRV	176	0.486***	0.347***	0.567***	0.409***	0.366***
PAT_NRES	143	0.168**	0.124**	0.174**	0.127**	0.049
INT_USER	189	0.657***	0.466***	0.522***	0.360***	0.288***
INTSECUR	192	0.610***	0.431***	0.489***	0.342***	0.251***
BBND_SUB	188	0.619***	0.441***	0.506***	0.360***	0.282***
ICT_CONTR	119	0.231**	0.151**	0.287***	0.185***	0.107*
LP_EMPL	121	0.748***	0.555***	0.645***	0.463***	0.408***
LP_HOUR	121	0.756***	0.564***	0.658***	0.471***	0.413***
FORGN_MV	154	0.167**	0.114**	0.149*	0.105*	0.045
STARTABUS	154	0.476***	0.331***	0.451***	0.320***	0.251***
BERD_GDP	38	0.542***	0.357***	0.267	0.181*	0.240**
BUX_GERD	38	0.439***	0.306***	0.243	0.181	0.212*
BFIN_HERD	38	0.045	0.061	-0.089	-0.041	-0.056
BRES_TOT	34	0.571***	0.405***	0.368**	0.266**	0.330***
HT_MFGEX	167	0.486***	0.337***	0.455***	0.320***	0.272***
IT_SERVEX	173	-0.034	-0.024	-0.016	-0.013	0.027
ITPROD_EX	174	0.367***	0.242***	0.346***	0.226***	0.173***
BF_SRVEX	145	0.535***	0.374***	0.491***	0.342***	0.290***
KBS_SRVEX	179	0.243***	0.164***	0.324***	0.219***	0.196***
PATP_GDP	38	0.373**	0.403***	0.669***	0.243**	0.240**
PATI_GDP	38	0.668***	0.471***	0.435***	0.317***	0.275***
PATB_GDP	38	0.614***	0.414***	0.393***	0.272**	0.206*
PATP_RES	136	0.278***	0.183***	0.309***	0.194***	0.169***
TM_DRES	142	0.138	0.079	0.192**	0.113**	0.07
TM_TOT	151	0.061	0.038	0.119	0.073	0.063

Table AIII.5 Rank correlation of extensive-margin knowledge-capital indicators with total FDI stock (outward and inward) and with GDP, 2000-2020 period, full country sample, but without tax-sheltering countries

Indicator name	Number of country observa-tions	Rank correlation with outward FDI		Rank correlation with inward FDI		PM: Kendall rank corr. (tau-b) with own GDP
		Spearman's rho	Kendall's tau-b	Spearman's rho	Kendall's tau-b	
HERD_S	38	0.830***	0.690***	0.809***	0.650***	0.824***
HRES_S	33	0.636***	0.458***	0.594***	0.443***	0.705***
HPER_S	36	0.723***	0.527***	0.689***	0.518***	0.762***
HFTE_S	36	0.726***	0.533***	0.682***	0.518***	0.724***
FEMRES_S	32	0.678***	0.516***	0.606***	0.472***	0.770***
GII_MAIN_S	138	0.741***	0.541***	0.704***	0.507***	0.400***
GII_INPT_S	123	0.783***	0.581***	0.735***	0.536***	0.433***
GERD_S	38	0.834***	0.662***	0.760***	0.576***	0.795***
GOVERD_S	38	0.688***	0.508***	0.633***	0.457***	0.698***
TOTRES_S	33	0.698***	0.538***	0.603***	0.462***	0.754***
GVRES_S	33	0.471***	0.341***	0.420**	0.303**	0.595***
TOTPER_S	34	0.735***	0.551***	0.657***	0.497***	0.775***
GVPER_S	35	0.524***	0.375***	0.469***	0.324***	0.620***
TOTFTE_S	35	0.771***	0.593***	0.687***	0.529***	0.771***
GVFTE_S	35	0.485***	0.351***	0.425**	0.287***	0.597***
GII_OUTP_S	122	0.729***	0.533***	0.727***	0.534***	0.433***
PAT_R_S	136	0.732***	0.545***	0.799***	0.600***	0.635***
JRNART_S	183	0.835***	0.644***	0.881***	0.705***	0.755***
PAT_NR_S	143	0.757***	0.562***	0.799***	0.609***	0.634***
BERD_S	38	0.821***	0.642***	0.706***	0.539***	0.724***
BRES_S	34	0.782***	0.608***	0.681***	0.523***	0.718***
BPER_S	37	0.765***	0.592***	0.683***	0.523***	0.730***
BFTE_S	36	0.786***	0.606***	0.695***	0.521***	0.718***
PCTPAT_S	38	0.861***	0.684***	0.749***	0.570***	0.664***
ICTPAT_S	38	0.846***	0.556***	0.713***	0.747***	0.718***
BIOPAT_S	38	0.902***	0.747***	0.771***	0.610***	0.642***
TMDRES_S	142	0.800***	0.606***	0.875***	0.689***	0.744***
TM_TOT_S	151	0.786***	0.589***	0.861***	0.675***	0.757***