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Virtuous cycles in knowledge transfers: Portals to more persistent and beneficial relations

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Virtuous cycles in knowledge transfers

Portals to more persistent and beneficial relations

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Abstract

Given the growing importance of external scientific knowledge for innovation, this paper examines firms' decisions regarding the choice between different forms of knowledge transfer, as well as the role these forms play in determining the duration of firms' knowledge transfer activities. We use firm-level panel data on knowledge transfer between firms and universities in Switzerland over the period from 1999 to 2017, comprising 4,382 firms and 6,151 observations. Our multinomial logistic regression shows that firms with temporary transfer activities have less financial slack and are severely constrained in their absorptive capacity. Even when these resources are taken into account, certain forms—such as research collaborations—appear to have a direct influence on the continuity of academic knowledge transfer, as such forms require organisational capital that is, in part, irreversible. Research collaborations, technical infrastructure and further training are significantly underutilised by firms with discontinuous relationships. Research consortia, on the other hand, are well suited to firms with limited financial and R&D resources. Consortia thus offer important avenues of access to the positive feedback loops (virtuous cycles) that, by increasing absorption capacity, lead to beneficial, permanent forms of transfer.

JEL: I23, O36, O38

1 Introduction

External scientific knowledge has become an increasingly important input for private-sector innovation (Arora, Belenzon, & Patacconi, 2018; Fleming, Greene, Li, Marx, & Yao, 2019; Marx & Fuegi, 2020). Academia is the most pivotal source of this kind of knowledge, which makes universities ever more central drivers of technological change. While a large literature documents the channels through which academic knowledge reaches firms and the benefits firms derive from it, comparatively few studies examine firms' *strategic* decisions about how — and how persistently — to engage in knowledge and technology transfer (KTT) with academia (Arvanitis & Woerter, 2009; Vick & Robertson, 2018; Barberá-Tomás, Azagra-Caro, & D'Este, 2022; Østergaard & Drejer, 2022). This paper addresses that gap.

We focus on two strategic dimensions of firms' engagement and on how they interact. The first is the *form* of transfer. Firms face a wide range of transfer channels, ranging from attending conferences, reading publications and continuing education, through various forms of human-capital mobility, to ambitious cooperative research projects with academic laboratories. Selecting one form rather than another reflects different strategies, constraints and opportunities. The second is the *temporal pattern* of engagement: some firms draw on academic knowledge continuously over long periods ("stayers"), others do so only temporarily ("entrants" and "leavers"), and still others never engage at all ("inactives"). What explains these temporal patterns, and how are they related to the forms a firm chooses?

The paper makes three contributions. First, we study two dimensions of firms' knowledge and technology transfer (KTT) choices jointly: (a) the specific form of transfer a firm chooses and (b) the continuity — or discontinuity — of its transfer activity over time. Second, we analyse the interdependence between the temporal patterns and the choice of particular forms, alongside more basic firm characteristics such as financial slack and absorptive capacity (Cohen & Levinthal, 1990; Bruneel, D'Este, & Salter, 2016). Thirdly, we show that the choice of form itself has an impact on durability. Certain forms are associated not only with greater innovation performance, but also with the development of absorptive capacity and organisational capital, such as trust, networks and shared codes of communication. This reduces the costs of future transfer activities and encourages the choice of transfer channels that foster more enduring relationships. This draws the firm into a *virtuous cycle* of knowledge transfer. However, as such forms are comparatively costly, they are not chosen by all firms. Firms with limited financial and absorptive

resources tend to prefer less costly forms, which are less advantageous and do not build up lasting assets. This study therefore aims to identify transfer forms that can support capability building and innovation performance at relatively low cost – forms that can act as *gateways* into the positive cycle.

We use firm-level panel data from three waves of the Swiss Knowledge Transfer Survey (SKTS) conducted in 2005 (Arvanitis, Kubli, Sydow, & Woerter, 2005), 2011 (Arvanitis, Ley, & Woerter, 2012) and 2018 (M. Beck, Hulfeld, Spescha, & Woerter, 2020), which together cover knowledge transfers between firms and academia in Switzerland from 1999 to 2017. Each wave covers the preceding six years and is based on the KOF Enterprise Panel (KEP), a stratified random sample drawn from the official Business and Enterprise Register (BER) of the Federal Statistical Office (FSO). The full panel comprises 4382 firms and 6151 observations (2582 from the 2005 survey, 1842 from 2011 and 1727 from 2018). We restrict attention to firms that participated in consecutive waves, which leaves 1287 firms and 2913 firm-year observations. The data cover transfers with national and international higher education institutions (HEI)[1] and distinguish nineteen transfer forms grouped into (i) informal contacts & networks, (ii) infrastructure & laboratories, (iii) personnel mobility & education, (iv) research, and (v) consulting.

Our empirical strategy proceeds in two steps. We first use descriptive statistics to compare how frequently entrants, leavers and stayers rely on each transfer form. We then estimate a multinomial logistic regression to assess how well each form distinguishes temporary from permanent transfer relationships, conditional on firm characteristics.

The descriptive evidence shows that firms which engage only temporarily ("entrants" and "leavers") rely heavily on informal transfer forms, whereas persistently engaged firms ("stayers") also draw on a broader and more resource-intensive set of channels, such as research collaborations and graduate recruitment. The regression results show that limited absorptive and financial capacities constrain entrants' and leavers' access to the high-benefit forms of KTT. Importantly, even after controlling for these resources, particular forms remain systematically associated with persistent relationships, which suggests that — beyond firm capacities — the form itself is directly related (conditional on absorptive capacity and financial slack) to the temporality of transfer activities.

Among these forms, research consortia stand out, particularly for firms with little or no prior transfer experience. Although consortia require a certain level of absorptive capacity,

[1] Henceforth abbreviated as *universities* for simplicity. Table A.II provides a list of the Swiss HEIs considered in the survey.

they are used more frequently by entrants and leavers than by stayers — plausibly because they do not require large upfront investments in irreversible assets such as extensive interpersonal networks with academic partners. In line with Foray and Woerter (2021), we argue that consortia can act as low-commitment entry points into transfer relationships with universities, allowing less experienced firms to collaborate with more established partners, build trust and develop a common "language". These are prerequisites for subsequently accessing more intensive forms of transfer, such as research collaborations or joint laboratories.

From a policy perspective, research consortia could thus serve as portals to more sustained and intensive knowledge and technology transfer relationships, helping firms accumulate the intangible assets and absorptive capacity that long-term engagement requires. However, this pathway is not assured. Consortia are also commonly used by leavers, an observation that admits alternative interpretations to which we return in the conclusion. The broader message is an opportunity for targeted innovation policy. Supporting research consortia as an entry mechanism is likely to be effective only if it is complemented by measures that build firms' absorptive capacities. Doing so could strengthen firms' ability to benefit from collaborative research, reduce their R&D costs and increase the importance of higher education institutions in the innovation ecosystem.

The remainder of the paper is organised as follows. Section 2 develops the conceptual framework, characterising the nineteen transfer forms and discussing the expected relationships between forms and temporal patterns. Section 3 presents the empirical setting (data and variables), and Section 4 develops the quantitative analysis. Section 5 discusses the findings from an innovation-policy perspective and suggests directions for future research.

2 Conceptual Framework

This section sets out the conceptual framework for this empirical analysis. We are interested in two strategic dimensions of corporate engagement in the field of knowledge and technology transfer with universities: (a) the form of transfer a company chooses, and (b) the temporal pattern of this engagement, i.e. whether a company transfers knowledge on a continuous or only a temporary basis. Our central approach is that these two dimensions are linked by the resources available to a firm, as well as by a path-dependent process of organisational learning. We proceed in four steps. First, we define the two

phenomena to be explained (2.1). We then characterise the heterogeneity of the forms of transfer and introduce the concept of the intensity of the transfer relationship as a conceptual tool for classifying this heterogeneity (2.2). Next, we present the two firm-level resources — absorptive capacity and financial capacity — which (co-)determine access to the more intensive forms (2.3). Finally, we draw on the concept of "organisational learning" to explain why the choice of a particular form can set a firm on a sustained, self-reinforcing (virtuous) path of knowledge transfer (2.4). Each step provides insights into the underlying dynamics, which we summarise in the concluding research-questions subsection (2.5).

2.1 Two dimensions of firms' transfer strategy

Companies that want to make use of academic knowledge face two analytically distinct decisions. The first concerns the form of knowledge transfer. The academic literature has emphasised that interaction between universities and industry is not based on a single channel, but on a portfolio of channels that differ considerably in terms of their organisational requirements and the nature of the knowledge conveyed — ranging from reading publications and attending conferences to jointly conducting research projects (Schartinger, Rammer, Fischer, & Fröhlich, 2002; D'Este & Patel, 2007; Perkmann, Salandra, Tartari, McKelvey, & Hughes, 2021). The choice of one form over another reflects different strategies, constraints and opportunities, and therefore also provides insight into the company behind this decision.

The second decision concerns the temporal pattern of the collaboration. Some companies draw on academic knowledge continuously over long periods, others do so only temporarily, while still others do not engage in such collaboration at all. Following the logic of Østergaard and Drejer (2022), we distinguish four patterns across two consecutive time periods: (a) firms that never engage in knowledge transfer (*inactive firms*), (b) firms that begin knowledge transfer (*entrants*), (c) firms that cease knowledge transfer (*leavers*), and (d) firms that continue knowledge transfer on an ongoing basis (*stayers*). Continuity and discontinuity are not random characteristics of transfer behaviour. They reflect whether a firm has succeeded in establishing and maintaining a productive relationship with the academic system.

The contribution of this paper lies in bringing these two decisions together. Rather than treating the form of transfer and the persistence of transfer as separate outcomes, we ask how they are interrelated, that is, whether certain forms are systematically associated with

continuity, whilst others are associated only with a temporary commitment, and whether such relationships reflect differences in firms' resources or are relatively independent of them. In the remainder of this section, we develop the conceptual framework required to pose this question precisely.

2.2 The heterogeneity of transfer forms and the intensity of partnerships

Forms of transfer differ in two economically significant respects. They differ in terms of the costs they incur for the firm and in terms of the benefits expected from them. On the cost side, the forms differ in terms of the transaction costs associated with searching for suitable transfer partners (search costs), establishing and maintaining the relationship, the time and effort required for the exchange, and the costs of building trust and mutual understanding, which necessitate complex exchange processes (Bruneel, d'Este, & Salter, 2010; Hughes, Lawson, Salter, Kitson, Bullock, & Hughes, 2016). Some of these costs are fixed and incurred upfront, while others are variable and scale with the intensity of the exchange. Importantly, some of them are largely irreversible. On the benefits side, the forms differ in terms of the extent and time horizon of the returns achieved — ranging from immediate problem-solving through consultancy to the longer-term gains from joint research and the recruitment of university graduates (Adams, Chiang, & Jensen, 2003; De Fuentes & Dutrénit, 2012; García-Vega & Vicente-Chirivella, 2020). The empirical literature consistently concludes that higher costs tend to go hand in hand with higher expected benefits, with joint research representing one extreme and informal contacts the other (Arza & Vazquez, 2010; Dutrénit, De Fuentes, & Torres, 2010).

Although our data distinguishes between nineteen individual forms — which we categorise into informal contacts and networks, research and innovation infrastructure, staff mobility and education, research, and consultancy (the full definitions can be found in Section 3) — the cost-benefit logic suggests that they can be ordered along a single underlying dimension, which we refer to as the *intensity* of the partnership. We conceptually define the intensity of a transfer form as the bundle of organisational resources — both financial and absorptive capacity — required to engage in that form, measured against the expected benefits. *High-intensity* partnerships, such as bilateral research cooperation, require considerable resources and the establishment of specialised organisational structures, but promise correspondingly high returns. *Low-intensity* partnerships, such as reading publications or attending further training courses, are cost-effective and inexpensive, but yield modest

and largely non-cumulative benefits. In this sense, intensity is a latent property that arises from the joint position of a form within a space comprising absorptive costs, financial costs and expected benefits. We do not measure it directly, but derive it empirically from this three-dimensional representation. We describe the construction of this three-dimensional map in Section 3.

Two characteristics of this heterogeneity are relevant to the following arguments. Firstly, forms are not isolated: formal and informal channels generally complement one another, so that the use of a more sophisticated form often makes it easier to utilise other, less costly forms (Grimpe & Hussinger, 2013). Secondly, and related to this, the more intensive forms are characterised not only by their costs, but also by the nature of the costs they entail. These are often investments in trust, communication and shared routines which, once made, do not need to be repeated. It is this second characteristic that links the choice of form to the continuity of the transfer, as we explain in Section 2.4.

2.3 Firm resources: absorptive and financial capacity

Whether a company has access to a particular transfer form depends on its resources. Two company-specific capabilities are crucial in this regard. They act as determining factors that influence both the costs a company must bear in order to utilise a particular transfer form and the benefits it can derive from it.

The first factor is *absorptive capacity* — the organisation's ability to recognise, internalise and apply external scientific knowledge (Cohen & Levinthal, 1990). Absorptive capacity is traditionally regarded as a by-product of a company's own research and development, but more recent work shows that it also depends on human capital, organisational structures and mechanisms of social integration, meaning that it cannot be reduced solely to research expenditure (Vega-Jurado, Gutiérrez-Gracia, & Fernández-de-Lucio, 2008; Bishop, D'Este, & Neely, 2011). It is also specific, that is, the ability to benefit from one particular type of external source differs from the ability to benefit from another. Absorptive capacity is therefore better understood as form-specific rather than as a single attribute (Schmidt, 2010). Where it is present, absorptive capacity enhances understanding of the transfer content and facilitates the integration of academic knowledge within the organisation. If it is lacking, costs rise and the benefits of external knowledge decline, thereby also reducing the incentive to engage with more advanced forms (Monjon & Waelbroeck, 2003; García-Vega & Vicente-Chirivella, 2020). It is therefore to be expected that absorptive capacity facilitates, in particular, access to high-intensity partnerships.

The second capacity is of a financial nature. Intensive transfers generally require expenditure before returns materialise, and the returns themselves are uncertain. Financial capacity eases this constraint. It enables a firm to pursue a broader, more exploratory and riskier range of transfer activities, and increases its tolerance for failure, while financially constrained firms are forced into a narrower range of cost-effective forms oriented toward immediate benefits (Greve, 2003; Bruneel et al., 2016). Financial constraints are a well-documented barrier to innovative activities (Mohnen, Palm, Van der Loeff, & Tiwari, 2008), and firm size and profit margins are common indicators of the financial capacity available to a firm (Rajan & Zingales, 1998; T. Beck, Demirgüç-Kunt, & Maksimovic, 2005). It is therefore expected that financial capacity influences a firm's ability to bear the upfront and irreversible costs associated with intensive transfer forms.

Taken together, these two capabilities determine which types of transfer are achievable for a company. This brings us to our first assertion.

Assertion 1. *Firms with greater absorptive capacity and greater financial capacity have access to more intensive transfer forms, while firms lacking these capacities are restricted to less intensive forms. Since intensive forms are also most closely associated with continued transfer activities (Section 2.4), differences in capacity should be reflected in differences in the duration of transfer activities.*

2.4 Path dependence and the sunk organizational capital in transfer relationships

While resources explain the choice of transfer forms, they do not, on their own, explain why transfer activities persist or do not. To understand this better, we draw on insights from organisational economics. Arrow (1974) notes that the information an organisation receives must be filtered, coordinated and condensed to be usable, which requires the creation of communication channels, information-processing routines and shared codes. Learning such a code is, as he puts it, "an act of irreversible investment" for the individual and thus an irreversible accumulation of capital for the organisation. David (1994) develops this insight further into a theory of path dependence. Since the acquisition and development of the codes and routines that coordinate action involve high costs, organisations develop their own identity. This means that these patterns from the past play a role in subsequent decisions. They constitute the path dependence of activities.

This framework can be directly applied to the establishment of a knowledge transfer relationship between a company and an academic partner. In order to foster a highly intensive form of this relationship, the company must build up what we refer to as *sunk organisational capital*. This includes the trust, interpersonal networks and shared codes of communication required to manage a complex exchange with the academic sector. Building up this capital is costly in the initial phase, but it is lasting and largely irreversible, and reduces the costs of subsequent transfer activities. Two complementary findings from the empirical literature underpin this mechanism. Firstly, previous experiences of collaboration have been shown to reduce the barriers companies face when working with universities, precisely because the investment in these relationships has already been made (Bruneel et al., 2010). Secondly, interaction with universities is in itself a means of building absorptive capacity, so that today's engagement enhances the firm's ability to engage tomorrow (Bishop et al., 2011). The decision to opt for an intensive form of collaboration therefore tends to have a self-reinforcing effect. It creates competencies and relational resources that make continuous and more comprehensive transfer activities more cost-effective and beneficial — a virtuous circle.

The opposite is true of low-intensity forms. Reading a publication or sending an employee to a continuing education course requires no investment in organisational capital and does not lead to its accumulation. Such forms keep exit costs negligible and preserve flexibility, but leave the company with hardly any relational or cognitive assets on which it could build. A company that operates exclusively through these channels runs the risk of remaining trapped in a pattern of low engagement and sporadic transfer activities — *a low-intensity trap* — from which there is little internal impulse to escape. This line of reasoning leads us to our second assertion.

Assertion 2. *Forms that require investment in sunk organisational capital are associated with the persistence of transfer, because the irreversible assets they create lower the cost of future engagement. Forms that require no such investment are associated with intermittent transfer activities. It is expected that this pattern will remain regardless of the companies' resource endowment.*

If Assertion 2 holds true, this raises an important economic policy question. There are two ways for a company to escape the "low-intensity trap". The first is to have sufficient absorptive and financial capacity from the outset to enter directly into high-intensity partnerships. The second — which is of greater interest where capacities are limited — is to enter via a form that offers the benefits and capacity-building of an intensive partnership

without requiring the same upfront investment in irreversible relationship resources. Research consortia are a possible form with such characteristics. They bring together less experienced firms with more established partners under a common organisational structure, enabling them to build networks, trust and a common language at comparatively low private costs, thereby developing the absorptive capacity required for more demanding forms of partnership (Foray & Woerter, 2021). According to this interpretation, consortia could serve as portals into the virtuous cycle and resolve the usual trade-off between the intensity of a partnership and its barriers to entry.

However, the portal mechanism is theoretically ambiguous, and we deliberately leave it open as a question rather than making a definitive statement. The very same low commitment that makes it easier to join a consortium also makes it easier to leave. A firm can participate, derive short-term benefits from it and then withdraw without ever accumulating the assets required for the transition to more intensive forms. Consortia could therefore be associated with entering the transfer (a portal) or with exiting it (a low-cost "revolving door" arrangement), and whilst the two interpretations differ in observation, they are a priori equally plausible. We formulate this tension as our third assertion.

Assertion 3. *Certain high-intensity forms with low barriers to entry — notably research consortia — may function as portals that allow resource-constrained firms to enter permanent transfer relationships. Whether they do so, or instead facilitate low-commitment and ultimately discontinuous transfer activities, cannot be said in advance and is an empirical question.*

2.5 Summary of research questions

The three assertions developed above identify the mechanisms we assume to be at work, but deliberately refrain from formulating directional hypotheses. Our empirical design is associative rather than causal. We are interested in how forms of transfer and temporal patterns are related, not in proving that forms cause temporal patterns. Although we attempt to avoid inconsistent results by using a detailed control vector, fixed effects and lagged variables, we cannot claim to have eliminated all endogeneity problems and to assert causal relationships. Furthermore, the theory itself provides no clear indication of causal relationships for important transfer forms, such as the role of research consortia, which means that Assertion 3 must in fact be left open and cannot be formulated as

a hypothesis. Against this background, it is more in line with the current state of the theory to base the analysis on research questions rather than to impose hypotheses whose direction of effect cannot be justified by the theory. We therefore structure the empirical analysis around two research questions, supplemented by a policy-oriented clarification of the second question.

Q1. Because the adoption of high-intensity partnerships is conditional on possessing or investing in absorptive capacity, is there a relationship between a firm's resources — and absorptive capacity in particular — and the persistence of its knowledge-transfer activities?

Q2. Conditional on firm resources, is there a direct relationship between the choice of a transfer form and the persistence of knowledge-transfer activities — that is, are some forms suited to durable engagement and others only to temporary transfer activities, irrespective of the resources of a firm?

Q2a. If such a direct relationship exists, are there high-intensity forms with low barriers to entry — in particular research consortia — that enable resource-constrained firms to enter continuous transfer relationships, thereby acting as portals to the virtuous cycle rather than as channels of low-commitment, discontinuous engagement?

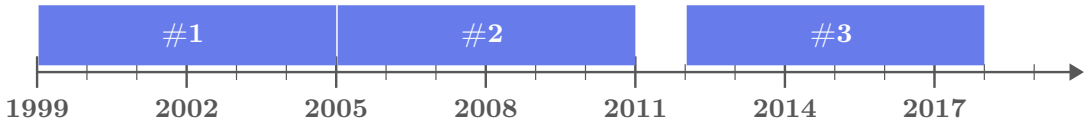
Answering these questions carries direct implications for innovation policy. If persistence is governed largely by absorptive capacity (Q1), then policies that build firms' capacity are a precondition for continuous university–industry relations. If, in addition, particular forms are independently tied to persistence (Q2), then the design of public support should attend not merely to whether firms transfer but to how. And if low-barrier intensive forms can serve as portals (Q2a), there is a case for promoting them as entry points — provided this is paired with measures that build the absorptive capacity without which the portal cannot lead anywhere. We return to these implications in the concluding section.

3 Data

3.1 Data source

The core of our data comes from three waves of the Swiss Knowledge Transfer Survey (SKTS) conducted in 2005 (Arvanitis et al., 2005), 2011 (Arvanitis et al., 2012), and 2018 (M. Beck et al., 2020) that yields firm-level data on knowledge transfers between

Figure 3-1: Temporal coverage of the surveys



Note: The years are labeled at the start of the year. Most variables in the questionnaires cover the entire six years, but some are measured only for the last three years or even just for the last year before the survey was conducted. We mention the specific time horizons for each variable when we introduce them further below.

firms and academia in Switzerland between 1999 and 2017. The KOF Swiss Economic Institute at the ETH Zürich (ETHZ) conducted these surveys as mandated by the State Secretariat for Education, Research and Innovation (SERI) and the ETH Board.

The surveys are based on the KOF Enterprise Panel (KEP), a stratified random sample drawn from the official Business and Enterprise Register (BER) of the Federal Statistical Office (FSO). It is stratified on geography, industry[2], and firm size. To account for changes in the population of firms and to combat sample attrition, it is updated every two years.

Although we base each survey on the same sample of firms, partial responsiveness yields an unbalanced panel of 4382 firms and 6151 observations, 2582 coming from the 2005 survey, 1842 from the 2011 survey, and 1727 from the 2018 survey.

Figure 3-1 shows the waves of this survey that were conducted on a sexennial basis[3] and measure the firm view of knowledge transfers between academia and the private sector in Switzerland. In line with the European Community Innovation Survey (CIS) and its U.S. siblings, the Annual Business Survey (ABS) and Business Enterprise Research and Development (BERD) Survey[4], it contains a section on general firm information including its foundation, ownership, employment, revenues, expenses, competition and the core research and development as well as innovation measures. In addition, it contains an extensive section on external knowledge sources and, most centrally, on academic knowledge transfer forms, partners, motives, obstacles and outcomes. Finally, it is related

[2]Table A.I shows the industries used and their composition of NACE sections and divisions.

[3]The funding switched between the first two and the last survey. The former were mandated and funded by the ETH Board and also cover the university view, while the latter was mandated and funded by the SERI and only covers the firm view. This switch explains the one-year gap between 2011 and 2012. For convenience, we abstract from this gap since it likely has a minor influence on our analysis.

[4]Both are conducted jointly by the U.S. Census Bureau and the National Center for Science and Engineering Statistics (NCSES) of the National Science Foundation (NSF). Their predecessors include the BRDS (2017-2018), BRDIS (2008-2017) and SIRD (1953-2007). Contrary to the CIS and the SKTS, it is an annual survey instead of a biennial one.

to the survey conducted by Bruneel et al. (2010) in the U.K. but covers a broader sample representative of the entire economy.

3.2 Variables

The surveys contain detailed information on the knowledge transfers of Swiss firms with academia. Table A.II[5] in the appendix lists all academic partners that we account for in our surveys. They specifically include all Swiss higher education institutions from the following three domains. The ETH domain includes both federal universities and the four affiliated research institutes. The second domain consists of the cantonal universities; of the ten cantonal universities, nine are part of our panel.[6] The third domain contains the seven regional universities of applied sciences. Additionally, we also ask for transfers with academia abroad, but not for specific institutions.

3.2.1 Temporal transfer pattern

We focus on the temporal dimension of knowledge and technology transfers and study firm behavior over two consecutive six-year periods. We denote by $d_{it}^d \in \{0,1\}$ whether firm i transfers knowledge and technology with domestic universities between $t-6$ and $t-1$, and by $d_{it}^f \in \{0,1\}$ whether firm i transfers knowledge and technology with foreign universities between $t-6$ and $t-1$.[7] Based on these two dummies, we define $d_{it} = d_{it}^d \vee d_{it}^f$, indicating whether firm i transfers knowledge and technology with domestic or foreign universities between $t-6$ and $t-1$.

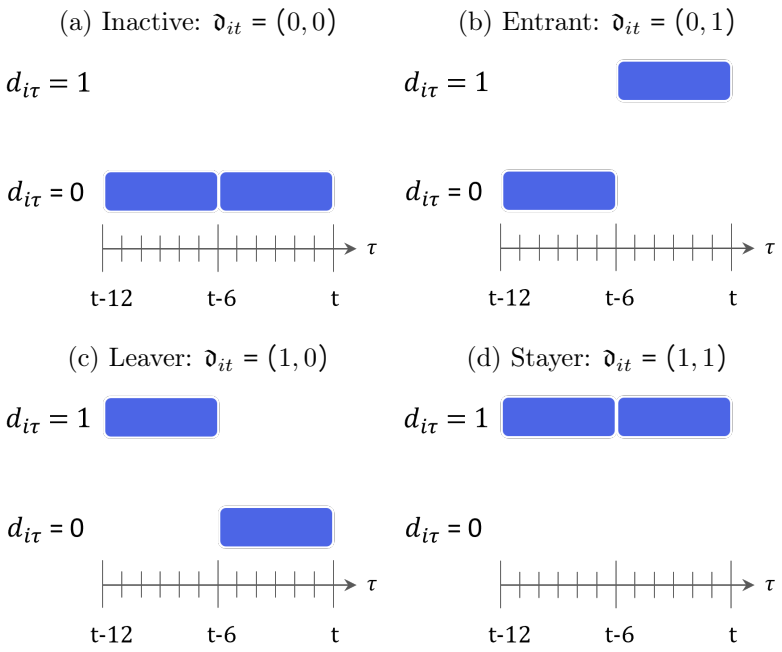
From the pair of consecutive observations $\mathfrak{d}_{it} = (d_{it-6}, d_{it})$ we define the four temporal patterns depicted in Figure 3-2. Since these patterns only materialize after two consecutive periods, we assign them at the end of the 12-year span. We call $\mathfrak{d}_{it} = (0,0)$ inactives, $\mathfrak{d}_{it} = (0,1)$ entrants, $\mathfrak{d}_{it} = (1,0)$ leavers and $\mathfrak{d}_{it} = (1,1)$ stayers. Østergaard and Drejer (2022) define temporal patterns in a similar way and call them "no collaborations", "initiation", "discontinuation" and "persistence", respectively. They consider consecutive

[5] Tables and figures in the appendix contain the prefix A.

[6] As mentioned in Table A.II, the University of Lucerne is not part of our panel, leaving us with nine cantonal universities.

[7] As depicted in Figure 3-1, there is a one-year gap between the end of the second wave and the beginning of the third wave. For simplicity, we treat the last survey as if it were conducted in 2017, thus closing the one-year gap and leading to a seamless six-year cycle. This saves us from messy notation that would require referencing the third wave in 2011 as $t+7$ and, vice versa, the second wave in 2018 as $t-7$. Since we look at relatively long periods covering six years, we deem this break in periodicity irrelevant for assessing transfer patterns.

Figure 3-2: Temporal transfer patterns



Note: The figure depicts the four possible temporal patterns that emerge from consecutive observations of firms' knowledge and technology transfer activities. The same logic applies to $\mathfrak{d}^d_{it} = \left(d^d_{it-6}, d^d_{it}\right)$ and $\mathfrak{d}^f_{it} = \left(d^f_{it-6}, d^f_{it}\right)$, which are based on transfer activities with domestic and foreign universities, respectively. The years τ are labelled at the beginning of the period.

three-year periods and focus on the collaborations of a firm with a specific university. We consider six-year periods and a broader set of transfers with either domestic or foreign academic partners. As such, we focus on a more general temporal pattern of knowledge and technology transfers. Inactives never transfer knowledge in the prior 12 years, entrants and leavers transfer knowledge temporarily in only one six-year period, and stayers transfer knowledge permanently in both prior periods. By focusing on consecutive participations, we lose 3238 observations from 2952 firms that participate only once and 143 firms that participate in the first and last survey wave but not in the middle one.

Table 3-1 shows the frequency of the temporal patterns from our remaining 2913 observations from 948 firms that participate in two consecutive waves and 339 firms that participate in all three waves. Since $\mathfrak{d}_{it}$ requires a pair of consecutive observations, this leaves us with 1626 observed patterns, two for each of the 339 three-time participants and one from each of the 948 two-time participants. Inactives are most frequent, followed by stayers that have continuous transfers over 12 years. Time-limited relationships, involving knowledge and technology transfer over only a six-year period, are the least common,

Table 3-1: Frequency of transfer patterns

		Frequency		
		$\mathfrak{d}_{it}$	$\mathfrak{d}_{it}^{d}$	$\mathfrak{d}_{it}^{f}$
Inactive	$\mathfrak{d}_{it} = (0,0)$	941	970	1356
Entrant	$\mathfrak{d}_{it} = (0,1)$	207	199	81
Leaver	$\mathfrak{d}_{it} = (1,0)$	182	173	90
Stayer	$\mathfrak{d}_{it} = (1,1)$	296	284	87

Note: The table reports the frequency of temporal transfer patterns based on pairs of consecutive observations $(it-6, it)$. The 948 firms that participate in only two consecutive waves record only one pattern. The 339 firms that participate in all three survey waves record two patterns, one for the first two survey waves (2005 and 2011) and one for the latter two survey waves (2011 and 2018). The cumulative frequency of $\mathfrak{d}_{it}^{f}$ is 12 patterns shorter than that of $\mathfrak{d}_{it}^{d}$ and $\mathfrak{d}_{it}$ since some firms fail to indicate whether they have foreign transfer in at least one wave.

while new entrants are slightly more common than exits. Combined, the two temporary patterns are about 30% more frequent than the continuous one. While this applies to domestic transfers, entrants, leavers, and stayers are equally (un)likely for foreign transfer activities. The higher frequency of inactives in foreign transfer activities shows that domestic transfers are far more prominent than foreign ones.

For the remainder of this paper, we link those transfer patterns to the granular transfer forms f_{it} introduced in the section below. A firm only records transfer forms if it has transfers, i.e., if $d_{it} = 1$. To link a transfer pattern (a pair of consecutive observations) to each transfer-active period (a single observation), we require a unique assignment mechanism, since the observation forms a temporal pattern with the preceding wave, $\mathfrak{d}_{it} = (d_{it-6}, d_{it})$, and with the succeeding wave, $\mathfrak{d}_{it+6} = (d_{it}, d_{it+6})$. If $\mathfrak{d}_{it} \neq \mathfrak{d}_{it+6}$, the transfer-active middle period belongs to two different patterns, requiring a unique assignment.

Our baseline mechanism gives precedence to scarcity, such that leavers dominate entrants, which dominate stayers. The assigned transfer pattern $tp_{it} = f(\mathfrak{d}_{it}, \mathfrak{d}_{it+6}) = f(d_{it-6}, d_{it}, d_{it+6})$ depends on the transfers in the past, present, and future period. In the baseline scenario it reads as

$$tp_{it} = \begin{cases} Entrant & \text{if } \mathfrak{d}_{it} = (0,1) \wedge \mathfrak{d}_{it+6} \neq (1,0) \\ Leaver & \text{if } \mathfrak{d}_{it+6} = (1,0) \\ Stayer & \text{if } (\mathfrak{d}_{it} = (1,1) \vee \mathfrak{d}_{it+6} = (1,1)) \wedge \mathfrak{d}_{it} \neq (0,1) \wedge \mathfrak{d}_{it+6} \neq (1,0) \end{cases}$$

based on transfer patterns $\mathfrak{d}_{it}$, or

$$tp_{it} = \begin{cases} Entrant & \text{if } d_{it} = 1 \wedge d_{it-6} = 0 \wedge d_{it+6} \neq 0 \\ Leaver & \text{if } d_{it} = 1 \wedge d_{it+6} = 0 \\ Stayer & \text{if } d_{it} = 1 \wedge \left(d_{it-6} = 1 \vee d_{it+6} = 1\right) \wedge d_{it-6} \neq 0 \wedge d_{it+6} \neq 0 \end{cases}$$

based on single-period transfers d_{it}. tp_{it} remains undefined if a firm has no transfers in the present period, or if there is no information on transfers in the present period, i.e., $d_{it} \in \{0, \varnothing\}$ where $\varnothing$ signals missing values, since those observations carry no information on transfer forms.

To reassure ourselves that the assignment mechanism does not drive our results, we consider two alternative mechanisms, defined in Appendix A.I.iii: a *reverse* mechanism that gives precedence to abundance (so that stayers dominate entrants, which dominate leavers), and a non-unique *double* mechanism that duplicates the 55 observations with distinct patterns $\mathfrak{d}_{it} \neq \mathfrak{d}_{it+6}$ and assigns each duplicate one of the two candidate patterns. Table 3-2 reports the resulting frequencies. In line with the frequencies of $\mathfrak{d}_{it}$ in Table 3-1, temporary relations are assigned less frequently than continuous ones under the unique mechanisms. Under the double mechanism, the frequency of entrants and leavers coincides with Table 3-1, whereas the frequency of stayers is almost twice as large, because every staying pattern is associated with two transfer-active observations; Appendix A.I.iii details this near-duplication. Reassuringly, the classification is robust across all three mechanisms.

3.2.2 Transfer forms

The second core piece of information for our purpose is the set of transfer forms a firm chooses. The single forms that we use in this study come from the Swiss Knowledge Transfer Survey (SKTS) described in Section 3.1. We provide a detailed conceptual discussion of the set of forms and their specific costs and benefits in Section 2, and their empirical positioning in the cost–benefit space in Section 3.3. We measure how important a transfer form was to a firm between $t-6$ and $t-1$ on a 5-point rating scale, i.e. $f_{it} \in \{1, 2, 3, 4, 5\}$, where 1 indicates no importance and 5 indicates very high importance. The scale is neither symmetric, as there is no neutral center, nor balanced, as the steps are unequal. It combines an intensive and an extensive margin, where the difference between 1 and 2 corresponds to the extensive margin and values 2 to 5 measure the intensive margin. We subsume the transfer forms in the 19×1 vector $\mathbf{f}_{it}$. We also

Table 3-2: Frequency of uniquely assigned temporal patterns

Baseline: Leavers $\succ$ Entrants $\succ$ Stayers			
	tp_{it}	tp^d_{it}	tp^f_{it}
Entrant	188	181	74
Leaver	182	173	90
Stayer	510	488	148
Reverse: Leavers $\prec$ Entrants $\prec$ Stayers			
	tp_{it}	tp^d_{it}	tp^f_{it}
Entrant	187	180	73
Leaver	147	138	78
Stayer	546	524	161
Double: Leavers $\sim$ Entrants $\sim$ Stayers			
	tp_{it}	tp^d_{it}	tp^f_{it}
Entrant	207	199	81
Leaver	182	173	90
Stayer	546	524	161

Note: Table A.III in the appendix shows all potential temporal patterns based on the triple $(d_{it-6}, d_{it}, d_{it+6})$ where $d_{i\tau} \in \{0, 1, \varnothing\}, \tau \in \{t-6, t, t+6\}$, their frequency in the sample, and the assigned pattern tp_{it} under the three assignment mechanisms. In the double assignment mechanism, we duplicate 55 observations where $\mathfrak{d}_{it} \neq \mathfrak{d}_{it+6}$, 54 observations where $\mathfrak{d}^d_{it} \neq \mathfrak{d}^d_{it+6}$, and 20 observations where $\mathfrak{d}^f_{it} \neq \mathfrak{d}^f_{it+6}$, explaining the difference in the cumulative frequency of temporal patterns between the baseline/reverse assignment and the double assignment. Stayers are far more frequent than entrants or leavers because they record two transfer-active periods, as opposed to only one for the two temporary relations.

use dichotomized measures $f^\tau_{it} = \mathbf{1}\left(f_{it} \geq \tau\right)$ to proxy whether the form was used, with a threshold of $\tau = 3$.

Table 3-3 shows the summary statistics of each single form. All variables are bounded between 1 and 5 due to our rating scale and record decent standard deviations that vary between 1 and 1.5 in absolute terms and between a third and two-thirds in relative terms compared to the sample mean.

Table A.V shows the Pearson correlation coefficients between the 19 transfer forms. The linear relation between the single transfer forms is low to moderate. The coefficients are

Table 3-3: Summary statistics on single transfer forms $\mathbf{f_{it}}$

		N	Mean	SD	Min.	Med.	Max.
Informal contacts & networks							
i.	Informal	842	3.01	1.09	1	3	5
ii.	Conferences	842	3.00	0.99	1	3	5
iii.	Publications	842	2.86	1.08	1	3	5
Infrastructure							
i.	Labs	842	1.61	1.01	1	1	5
ii.	Infrastructure	842	2.18	1.24	1	2	5
Education & mobility							
i.	Recruiting	842	2.74	1.48	1	3	5
ii.	Contacts to labs	842	2.16	1.21	1	2	5
iii.	Internships	842	2.45	1.27	1	2	5
iv.	Thesis	842	2.61	1.24	1	3	5
v.	Dissertations	842	1.72	1.03	1	1	5
vi.	Sabbaticals	842	1.82	1.07	1	1	5
vii.	Seminars	842	1.67	0.95	1	1	5
viii.	Lectures	842	1.75	1.04	1	1	5
ix.	Further education	842	2.88	1.12	1	3	5
Research							
i.	Research cooperation	842	2.23	1.30	1	2	5
ii.	Contract research	842	1.62	1.02	1	1	5
iii.	Research consortia	842	1.62	1.01	1	1	5
Consulting							
i.	Expertise	842	2.04	1.10	1	2	5
ii.	Consulting	842	2.19	1.10	1	2	5

Note: Table A.IV in the appendix shows a detailed description of the individual transfer forms. We base all reported statistics on observations with an assigned transfer pattern based on domestic transfers, i.e., on $tp_{it}^{d} \neq \varnothing$. The number of observations aligns with the cumulative frequencies under the unique baseline and reverse assignment mechanisms reported in Table 3-2, as well as with the number of observations in the regression results from specification (M0) in Table 4-5.

moderate within groups of forms and high within research and consulting. Between groups, the linear relation is low, except for research-based transfer forms and either infrastructure-related or mobility-related forms, which show a stronger linear relation. This implies that the single transfer forms do not carry purely idiosyncratic variation. However, since they all measure some form of knowledge transfer and only record moderate correlations, we

can say with confidence that each variable contains sufficiently independent information and that high multicollinearity is absent. Nevertheless, we provide formal evidence for the regression analyses in Table A.VII that further supports the conclusion that high multicollinearity between the forms is not an issue.

3.2.3 Firm-level variables

We use firm-level variables in our regression analyses, partly as control variables for the effect of forms and partly as explanatory variables of the temporal patterns themselves. The 9×1 vector $\mathbf{x}_{it-6}$ subsumes the firm-level variables comprising firm characteristics and innovation activities. We use start-of-period values measured at the end of $t-7$, where t is the year the survey was conducted, to prevent bad controls, since these measures might themselves be influenced by knowledge transfers. Section A.I.v in the appendix outlines how we retrieve those lagged values.

Firm characteristics We include five firm characteristics: size, gross margin, age, distance to the nearest university, and human capital. We measure firm size as the number of employees at the end of $t-7$ in full-time equivalents (FTE). We measure the gross margin as the ratio of gross income at the end of $t-7$ to sales at the end of $t-7$. We proxy the gross income as sales minus the expenses for intermediate goods at the end of $t-7$, which approximates the firm's true cost of goods sold (CoGS). The size of the firm and the gross margin are our measures of a firm's financial capacity. Larger firms have easier access to external finance and generally hold a stronger cash-flow position than smaller firms (Rajan & Zingales, 1998; T. Beck et al., 2005), which is further ascertained by the gross margin. We measure the distance to the nearest university as the geodesic between the location of the firm at the end of $t-7$ and the location of the nearest main building of a university. We also measure firm age at the end of $t-7$. Finally, we measure the firm's human capital as the number of employees with a tertiary degree at the end of $t-7$ in FTE.

Table 3-4 shows the summary statistics for the start-of-period variables, i.e., $\mathbf{x}_{it-6}$. The average number of employees at the start of the period is roughly 630 full-time equivalents (FTE). While the firms in this sample are relatively large, the distribution is heavily right-skewed, and the median is near 130 FTE. The distribution of employees with a tertiary degree is similarly skewed, with a start-of-period mean of 55 FTE and a median of 5 FTE. The end-of-period average age is 68 and spans firms from 4 to 309 years old.

Table 3-4: Summary statistics of firm-level variables $\mathbf{x_{it-6}}$

		N	Mean	SD	Min.	Med.	Max.
			I. Firm characteristics				
i.	Employees	840	628.32	3220.41	3	126	43038
ii.	Age	840	62.03	42.19	0	53	303
iii.	Gross margin	840	0.61	0.20	.07	.61	.99
iv.	Nearest university	840	15.62	14.64	.06	13	91
v.	Employees with tertiary degree	840	54.73	268.86	0	5	3787
			II. Innovation activities				
i.	R&D expenses	840	8.91	97.81	0	.2	2674
ii.	New products	840	0.60	0.49	0	1	1
iii.	Improved products	840	0.58	0.49	0	1	1
iv.	Process innovations	840	0.55	0.50	0	1	1

Note: We base all reported statistics on observations with an assigned transfer pattern based on domestic transfers, i.e., on $tp^d_{it} \neq \varnothing$. Two firms are younger than six years in t and hence do not exist at the start of the period. Employees are measured in full-time equivalents (FTE), age is reported in years, distances correspond to geodesics and are in kilometers (km), and R&D expenses are in million CHF.

The two observations with end-of-period ages below six years are also the ones that drop when we look at start-of-period values. The gross margin, calculated as the ratio of gross income to turnover, ranges from .07 to .99 with a mean and median of .61. Firms are highly immobile over the years and are on average 15.6 kilometers away from the nearest university. Some are as close as 60 meters and some as far away as 90 kilometers.

Innovation activities We further use a firm's innovation inputs and outputs to see how they relate to the temporal transfer patterns. We use the natural logarithm of the total expenses on R&D at Swiss facilities to proxy innovation inputs (Cohen, 2010). By the design of the questionnaire, R&D expenditure is recorded for the year preceding a survey; for our start-of-period measure, entering $\mathbf{x}_{it-6}$, this therefore refers to $t-7$. R&D expenses and human capital also proxy a firm's absorptive capacity (Cohen & Levinthal, 1990). For innovation outputs, we use binary indicators for whether a firm introduced product[8] or process innovations between $t-9$ and $t-7$. We split the product-innovation indicator into two parts that measure radical and incremental innovations via the presence of new and improved products, respectively (Belderbos, Carree, & Lokshin, 2004; Arvanitis &

[8] Product innovations comprise new or improved goods and services.

Woerter, 2009). Table 3-4 shows the summary statistics. The average start-of-period R&D expenses are about 9 million CHF, while the median is 0.2 million CHF. Sixty percent of firms had new products, 58% improved products, and 55% process innovations 9 to 7 years before observation.

3.3 Mapping transfer forms in the cost–benefit space

Having introduced the transfer forms (Section 3.2.2) and the firm-level variables (Section 3.2.3), we now operationalize the notion of partnership *intensity* introduced in Section 2. To obtain a normative grip on how each transfer form relates to costs and benefits, we empirically map the forms along the three dimensions of absorptive capacity, financial capacity, and expected benefits. In this way, we can predict which firms have access to which forms, depending on the relation between their idiosyncratic resources and the costs and expected benefits of the transfer. In the analyses of Section 4, we test those predictions and uncover how the forms chosen relate to firms' temporal transfer patterns.

3.3.1 Constructing the map

First, we construct comprehensive measures of a firm's absorptive and financial capacity. We rely on start-of-period measures from the SKTS laid out in Section 3.1.

For the absorptive capacity, we use a firm's human capital and R&D skills. The first dimension comprises the number of employees with a tertiary degree $x_{it-6}^{empl:tert}$ and the labor expenses per employee $x_{it-6}^{cost:labor}$. The second dimension comprises the number of employees in R&D $x_{it-6}^{empl:rnd}$ and the total expenses on R&D $x_{it-6}^{cost:rnd}$. We transform those variables into a comprehensive measure of the firm's absorptive capacity by applying the natural logarithm with the addition of 1 to maintain the extensive margins,[9] normalizing their support to $[0, 1]$ to make them scale invariant,[10] then taking the geometric average of the two human-capital variables and of the two R&D-skill variables,[11] and finally taking the geometric average of those two variables to arrive at $x_{it-6}^{absorptive}$.

For the financial capacity, we use a similar measure that combines the firm's number of employees x_{it-6}^{empl} and its gross margin x_{it-6}^{margin}, which together proxy financial slack

[9] $\dot{x}_{it-6}^{m} = \ln(x_{it-6}^{m} + 1)$ where $m \in \{empl : tert, cost : labor, empl : rnd, cost : rnd\}$.

[10] $\ddot{x}_{it-6}^{m} = (\dot{x}_{it-6}^{m} - \underline{\dot{x}}_{it-6}^{m})/(\overline{\dot{x}}_{it-6}^{m} - \underline{\dot{x}}_{it-6}^{m})$ where $\overline{\dot{x}}_{it-6}^{m}$ is the maximum and $\underline{\dot{x}}_{it-6}^{m}$ the minimum.

[11] $x_{it-6}^{human} = ((\ddot{x}_{it-6}^{empl:tert} + 1) * (\ddot{x}_{it-6}^{cost:labor} + 1))^{.5}$ and $x_{it-6}^{rnd} = ((\ddot{x}_{it-6}^{empl:rnd} + 1) * (\ddot{x}_{it-6}^{cost:rnd} + 1))^{.5}$, respectively, where the addition of 1 prevents the extensive margin from dominating.

(Rajan & Zingales, 1998; T. Beck et al., 2005). Again, we apply the natural-logarithmic transformation to the former and a logistic transformation to the latter, normalize their support to $[0, 1]$, and use the geometric average of those transformed variables to arrive at $x_{it-6}^{financial}$.

To rank every transfer form along these two dimensions, we construct binary variables that indicate whether a firm uses the given form.[12] Our prime interest is to measure whether absorptive and financial capacities constitute barriers to using a transfer form. As such, we look at the lower end of the distribution of those measures for firms that use a given transfer form. Specifically, we take the 3^{rd}, 4^{th}, 5^{th}, 6^{th}, and 7^{th} quantile of each metric for firms that use a form,[13] normalize the support of those quantiles to span $[0, 1]$ across forms, construct the average of those scores across the quantiles,[14] and finally normalize that measure to span $[0, 1]$. We use multiple quantiles at the lower end of the distribution to make the measure more reliable. This yields a score between 0 and 1 for each form that indicates the relative importance of absorptive and financial capacities for using a certain transfer form.

The final piece of the puzzle is the expected benefits of the forms. We use the end-of-period sales x_{it}^{sales} and dummies for the launch of new x_{it}^{new} and improved products $x_{it}^{improved}$ to measure the benefits from transfer. We regress each measure on each form and control for the start-of-period metrics that underlie the measures of absorptive and financial capacity, i.e. x_{it-6}^{empl}, $x_{it-6}^{empl:tert}$, $x_{it-6}^{empl:rnd}$, $x_{it-6}^{cost:labor}$, $x_{it-6}^{cost:rnd}$, x_{it-6}^{margin}, as well as fixed effects for each survey wave, NACE-II, and NUTS-II. We then take the standardized coefficients to make the effect scale invariant, construct the weighted average across benefits where x_{it}^{sales} receives a weight of $1/5$ and the product-innovation dummies a combined weight of $4/5$ that is split $2/3$ to x_{it}^{new} and $1/3$ to $x_{it}^{improved}$, and normalize the resulting scores such that they span $[0, 1]$ across the transfer forms.

3.3.2 Where do the forms locate?

Figure 3-3 shows our empirical map of the transfer forms in the cost–benefit space. The axes measure the cost dimensions, while the size of the dot measures benefits. Specifically, the horizontal axis measures the absorptive capacity required for a specific form, while the

[12] Section 3.2.2 outlines that the forms f_{it} are measured on a 5-point ordinal scale. We transform them into binary measures based on a threshold of 2, i.e. $f_{it}^2 = \mathbf{1}(f_{it} \geq 2)$.

[13] $x_{it-6}^{m,f_{it}^2,q}$ where $m \in \{absorptive, financial\}$ is the metric, f_{it}^2 indicates that it applies to firms that use the form, and $q \in \{3, 4, 5, 6, 7\}$ indicates the quantile.

[14] i.e. $1/5 * \sum_q x_{it-6}^{m,f_{it}^2,q}$.

vertical axis measures the corresponding financial capacity. Each dimension is normalized to span $[0, 1]$, and each form is positioned in these three dimensions according to the procedure outlined above.

The resulting map aligns well with the literature as well as with our grouping of the forms. In the bottom-left corner, we find **low-intensity forms** that require little financial and absorptive capacity in exchange for negligible benefits. This cluster includes reading academic publications,[15] informal personal contacts, attending academic workshops, seminars, or conferences, as well as further education.

At the other end of the spectrum, we find **high-intensity forms** that require high financial and absorptive capacities. They include contract research, research consortia, and research collaboration. In line with the literature mentioned above, collaborations are highly beneficial for companies, while consortia are comparatively less beneficial but also require less absorptive capacity. Interestingly, contract research generates benefits similar to consortia but comes at higher financial cost and requires higher absorptive capacity.

A third group is located in the middle and comprises consulting, expertise, lectures, and infrastructure. These require average financial and absorptive capacities but yield limited benefits.

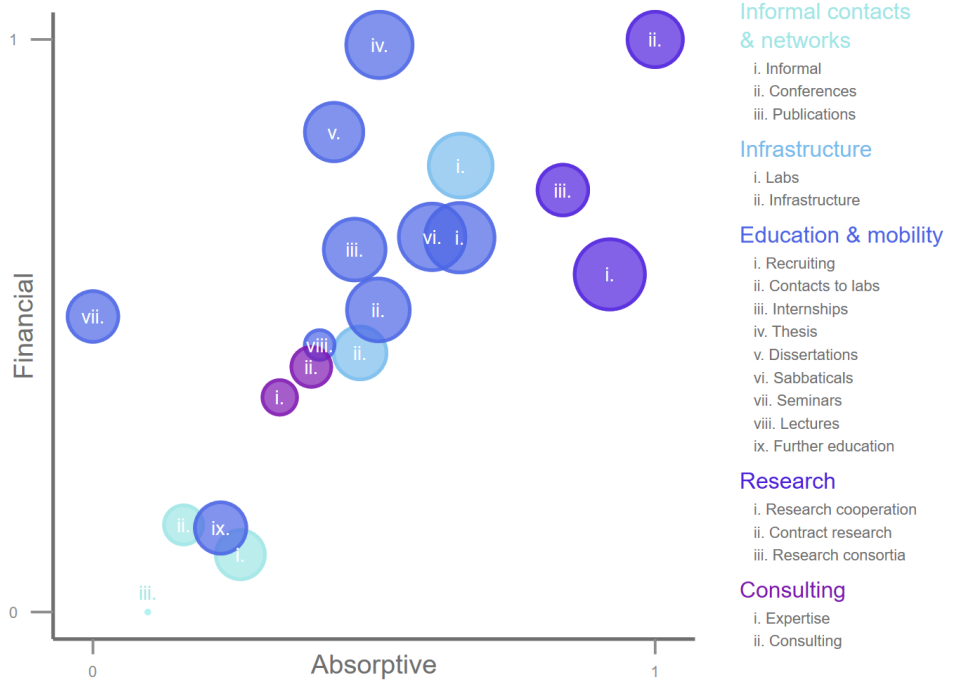
The last group of forms requires average absorptive capacities but above-average financial capacities. This category comprises the mobility-related forms in the education & mobility group — specifically recruiting, contact to labs by graduates, internships, thesis, dissertations, and sabbaticals — as well as labs from the infrastructure group. All of these forms yield substantial benefits, and particularly the recruiting of graduates and industrial sabbaticals by academics, which require slightly higher absorptive capacities than the rest. Also striking is that labs are substantially more costly than infrastructure but yield only somewhat larger benefits.

4 Analysis & results

We use a twofold approach. First, we use descriptive statistics to inspect the relevance of each singular transfer form for the continuity of transfers. This allows us to study which channels are most important in an absolute sense for entrants, leavers, and stayers. Second, we study how well each transfer form is suited for temporary and permanent

[15] This comprises a broader notion of "academic" publications that includes the professional literature targeted at non-academic groups.

Figure 3-3: Where are the forms of knowledge transfer located in the cost–benefit space?



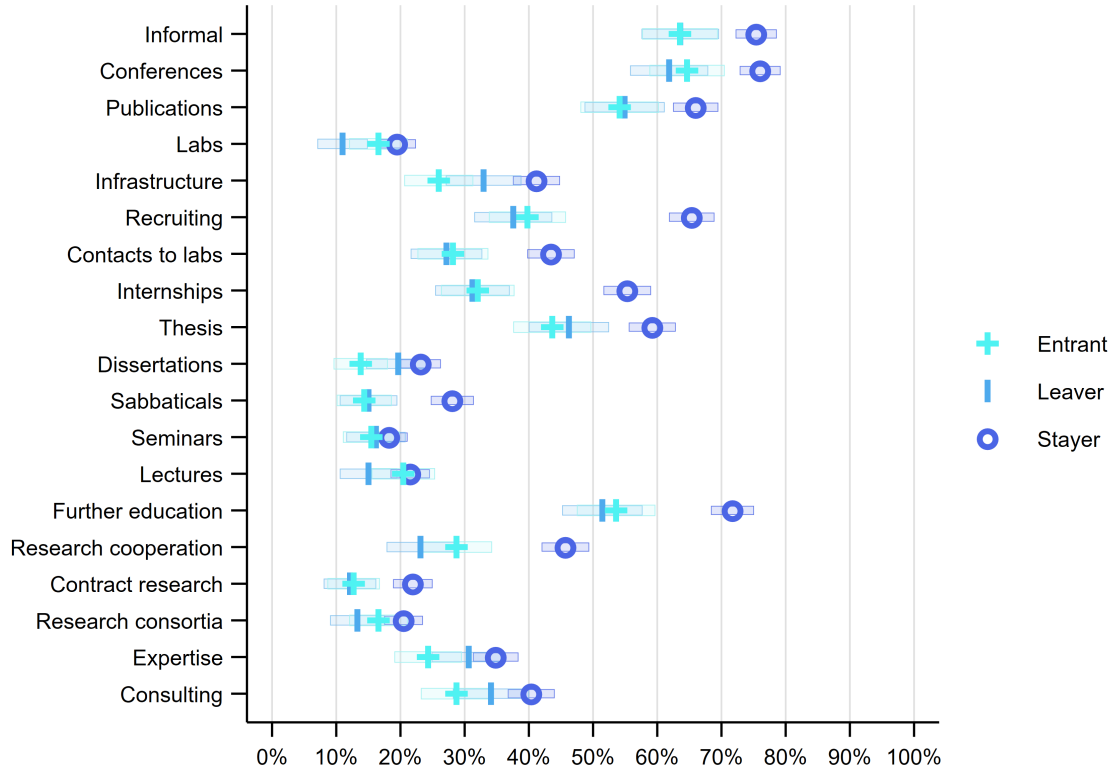
Note: The figure shows the transfer forms in the cost–benefit space. The x-axis measures a firm's absorptive capacity, the y-axis its financial capacity, and the size of the dot marks the form's expected benefits.

relations. We use multinomial logistic regression to explain how the transfer forms are associated with changes in the odds of entering and leaving against staying. The regression framework allows us to control for additional covariates such that we can analyze if the set of forms differs between the three temporal transfer patterns simply due to differences in firm characteristics like financial or absorptive capacities associated with those patterns or if they exist independent of those factors.

4.1 Descriptive analysis

In a first step, we look at the relevance of each singular transfer form for entrants, leavers, and stayers separately. We use the dichotomized versions of the singular forms. If a firm records a score of 3 or higher on the five-point rating scale, we deem it important to the firm. Based on this measure, we can assess how large the share of firms is that see a singular form as important. This allows us to study the absolute relevance of individual knowledge transfer forms for entrants, leavers, and stayers.

Figure 4-4: What forms do entrants, leavers, and stayers use?



Note: The figure shows the share of firms that use a given transfer form f_{it} by temporal domestic transfer patterns tp^d_{it}. Since we measure forms on a 5-point rating scale we dichotomize them based on a threshold $\tau = 3$, i.e. $f^3_{it} = \{f_{it} \geq 3\}$, where 1 indicates using the form and 0 indicates not using the form. We calculate the shares as the average dichotomized values per group $j \in \{Entrant,\ Leaver,\ Stayer\}$, i.e. as $\bar{f}^3_j = \sum_{it:tp_{it}=j} \left(f^3_{it} / \sum_{ku:tp_{ku}=j} 1 \right)$. 90% confidence intervals surround the group means.

Looking at figure 4-4, we note immediately that entrants have a limited range of preferred channels. Only informal contacts, conferences, publications, and further education are considered as important by more than 50% of entrants.[16] While more than half of all stayers also see those forms as important, they also highlight the importance of several education and mobility transfer forms (recruitment of graduates, internships, and joint thesis). Well around 40% of stayers view research cooperation, maintained contact to labs of hired graduates and the use of academic infrastructure as important. The fact that so many forms are highlighted as important by stayers suggests some multiplier

[16]The fact that entrants select informal contacts as important seems logical at first glance but is far from obvious since they require know-who as well as trust-building mechanisms. Similarly reading publications and attending conference requires prior know-how of the scientific matter. Our econometric estimations answer some of these questions.

effects and increasing returns to transfer partnerships. For instance, embarking on a research cooperation project implies long standing relations involving many people on both sides, the allocation of specific resources into the project (teams, infrastructures) and the development of organisational capital (social networks, trust, communication codes). This creates opportunities to "add" other transfer forms at minimal cost since the fixed cost of establishing cooperation and trust has been incurred from the start of the initial project. Then, it might be relatively easy for the engaged firm to read the academic publications of the partner, get the students of the concerned lab for internship or thesis, or use the tech infrastructure of the academic partner. Furthermore, a research cooperation could eventually lead to the recruitment of the graduates originally involved in the cooperation as PhD student or postdoc. The effects of the forms that involve a significant engagement of the firm are likely to be persistent (beyond the end of the initial project) and multi-dimensional because the initial project generates opportunities for activating many other forms of knowledge transfer at negligible cost. It is exactly these effects that create the virtuous cycles. Some forms require specific resources like financial slack or absorptive capacities but also foster those resources afterwards which then affects the costs and benefits of future transfer forms and a firm's future investment in those forms.

A key issue is to understand who uses forms which involve significant engagement and investments. We already observed that most entrants see informal forms, joint thesis, as well as further education frequently as very important. As mentioned above, these are low-cost, low-commitment forms that do not offer many opportunities to strengthen transfer activities through other forms, as new entrants may lack the financial resources and/or internal capacity/capability to pursue more committed transfer forms such as research collaborations or contract research, or to use university infrastructure.

Leavers have a similar preference pattern as entrants. They also see informal forms, joint thesis, and further education as most important which are all forms that do not imply high fixed costs to construct partnerships.

There is, thus, a logic behind the simple use of services and information. This comprises low-cost activities that give the company flexibility in its future decision-making, as exit costs are negligible. However, this does not allow the firm to generate and accumulate intangible assets, such as knowledge and networks. There is another logic referring to the co-production of knowledge, whereby companies become active partners in the process of knowledge generation and use. In such case, the firm does accumulate new intangibles

and is facing many opportunities to augment and diversify its forms of knowledge transfer. We thus conjecture that the probability of leaving is likely to be higher for firms that limit their transfer activities to informal forms and further education, while it is likely to be lower for firms that move to more involved and costly transfer activities.

If we now only look at the importance of forms, without considering the classification of firms into entrants, leavers, and stayers, informal forms and further education emerge as very important in all cases. The reason again is the negligible fixed cost of activating these forms. They allow for low-cost connections which do not predetermine future strategies but also do not allow for the creation of assets as a base for further collaborations and partnerships in the next period.

The highlight on "further education" is by itself an interesting descriptive result since incentives and career path in the academia are not structured in a way which would encourage faculties to undertake further education activities. This is particularly true when engaging in a further education program does not mean delivering the same courses which are offered to BA or MA students but means redesigning courses in a significant way to fit a very different audience. This finding should motivate universities and other actors of the public research system to explore the ways in which certain incentives could be modified or created to better meet the needs of firms. For example, to what extent are further education activities incorporated into the job description of teaching staff and appreciated in terms of career development? It is finally notable that some preference disparities are quite salient within groups of forms. For example, we can observe a stronger preference for infrastructure opposed to joint labs within the infrastructure-based forms. Similarly, research cooperation is more prominent opposed to contract research and research consortia within the research-based forms. Such disparities are a justification to put our observations at a finer level of granularity than the level of the five general categories.

4.2 Regression analysis

4.2.1 Model

From section 4.1 we learned that stayers use all transfer forms more intensely than entrants or leavers. The specific profile of transfer forms is however distinct between temporal patterns. Recalling the conceptual framework, it is likely that firms with high absorptive and financial capacities are better suited for high-intensity transfer forms like R&D collaborations. Such firm characteristics help explain the differences in the chosen

set of transfer forms between entrants, leavers, and stayers which provides a direct answers to our first research question (Q1). Yet, there might also be some forms that are simply unsuited for temporary relations independent of the resources of a firm. In line with our second research question (Q2), firms with similar resources may decide differently with regard to temporary or continuous use of academic knowledge as well as the forms chosen, for example if further factors like trust or existing networks matter for both. We use a multinomial logistic regression model described by the following equation to respond to the research questions:

$$\ln\left(\frac{P\left(tp_{it}^{d}=j\middle|\mathbf{X}_{it}\right)}{P\left(\mathrm{tp}_{it}^{d}=Stayer\middle|\mathbf{X}_{it}\right)}\right)=\alpha_{0,j}+\mathbf{f}_{it}^{\prime}\boldsymbol{\beta}_{0,j} \tag{M0}$$

$$\ln\left(\frac{P\left(tp_{it}^{d}=j\middle|\mathbf{X}_{it}\right)}{P\left(\mathrm{tp}_{it}^{d}=Stayer\middle|\mathbf{X}_{it}\right)}\right)=\alpha_{1,j}+\mathbf{f}_{it}^{\prime}\boldsymbol{\beta}_{1,j}+\mathbf{x}_{it-6}^{\prime}\boldsymbol{\gamma}_{1,j} \tag{M1}$$

where $j \in \{Entrant, Leaver\}$. The categorical dependent variable tp_{it}^{d} measures the temporal domestic transfer pattern of firm i in year t as introduced in Section 3.2.1. In our main specification we use the baseline mechanism that assigns observations that belong to two distinct patterns to a unique pattern based on scarcity preferring leavers over entrants and entrants over stayers.[17] We choose stayers as our baseline and compare the two temporary relations j against it. As evident by the subscript j on the coefficients β, the regression model allows the covariates to impact entrants and leavers differently. We focus on the coefficients $\boldsymbol{\beta}_{0,j}, \boldsymbol{\beta}_{1,j}$, and $\boldsymbol{\gamma}_{1,j}$. The former relates the transfer forms and the temporal transfer patterns. The 19×1 vector $\mathbf{f}_{it}$ contains the variables that measure the importance of single transfer forms on a 5-point rating scale. The latter measures the association between firm-level variables and the temporal transfer patterns. The 9×1 vector $\mathbf{x}_{it-6}$ contains the start-of-period firm-level variables described in Section 3.2.3.[18] Since these variables are partially influenced by the transfer forms during the 6-year period, i.e., by $\mathbf{f}_{it}$, which seems especially likely for the number of academics employed or expenses on research and development, we use the lagged variables to prevent bad controls. They serve a dual role. First, they act as control variables to purge the association between forms and patterns of these firm influences. This delivers a clearer picture if the lower usage of transfer forms by firms with temporary relations stems from differences in these

[17] It is worth stressing out that our main objective is to uncover associations rather than causations. We care about how transfer forms are related to transfer patterns and not if forms cause patterns. We only care for a correct assignment that guarantees truthful associations and neglect potential endogeneity.

[18] We apply the logarithmic and logistic transformation for three reasons: i) to extend the non-negative variables to the entire scale of real numbers, ii) to transform the right-skewed log-normal distribution to a normal distribution, and iii) to gain a nicer interpretation on our parameter estimates.

observables, particularly with respect to our proxies for absorptive capacity and financial capacity, or if it exists irrespective of them. Second, they act as explanatory variables that help to predict the transfer patterns.

4.2.2 Estimation

Model M0

Table 4-5 shows the estimates of both specifications using maximum likelihood. The first step we examine how well the transfer forms alone can distinguish the three temporal patterns and which forms are most meaningful in distinguishing them. The first two columns under the heading (M0) correspond to the restricted model that only includes $\mathbf{f}_{it}$. The left column shows the estimates for $j = Entrant$, the right those for $j = Leaver$. In accordance with the column on domestic transfers tp^d_{it} in the first panel of table 3-2 using the baseline assignment, the regression uses a sample of 842 observations including 488 Stayers, 181 Entrants, and 173 Leavers.[19] *Goodness of fit* We first test if the transfer forms have a significant explanatory power for the three temporal patterns (H0: $\boldsymbol{\beta}_{0,Entrant} = \boldsymbol{\beta}_{0,Leaver} = 0$) via a likelihood ratio test of the fitted model against one that only includes intercepts. H0 is clearly rejected (χ^2-statistic 154.7, p-value 5.1e-16) suggesting that the transfer forms jointly indeed have a significant explanatory power. McFadden's pseudo R^2 (0.095) further stresses the point that the explanatory power of the model is good. We also test the hypotheses that each pattern individually is indistinguishable from the others with respect to $forms_{it}$. The three hypotheses that $\boldsymbol{\beta}_{0,Entrant} = 0$, $\boldsymbol{\beta}_{0,Leaver} = 0$ and $\boldsymbol{\beta}_{0,Entrant} = \boldsymbol{\beta}_{0,Leaver}$ are again tested with likelihood ratio tests. The first two hypotheses are clearly rejected (χ^2-statistic 84.56 and 98.72, p-value 3.0e-10 and 9.1e-13) and the third is rejected at a 10% significance level but cannot be rejected at a 5% level (χ^2-statistic 27.94, p-value 8.5e-2). Taken together, the profile of transfer forms is clearly distinct between firms with temporary and continuous knowledge transfers and to a lesser degree also between the two temporary patterns. While this justifies that we distinguish between entrants and leavers to study the asymmetric associations between covariates and these two temporary transfer patterns, we also report robustness checks in section 4.2.3 that group the temporary transfers and compare them against the continuous pattern of stayers. One justified concern is the presence of severe multicollinearity that could heavily impair the results. To assess how severely multicollinearity impairs our regressions we calculate the variance inflation

[19] The results due to the other assignment mechanisms are presented in table A.X. These are not substantially different from those presented here.

factor of each transfer form controlling for the remaining set of covariates of a given regression equation. Column M0 in table A.VII shows the variance inflation factors for the baseline specification in table 4-5. The variance inflation factors are between 1.37 and 2.47 indicating that the remaining set of forms purge between 27% and 60% of the variation in the left-out form. Heuristically, any variance inflation factor above 5 or 10 is cause for concern. This implies that any idiosyncratic variation, i.e. variation that is linearly independent of the other covariates, above 10% or 20% is sufficient. We maintain between 40% and 73% of idiosyncratic variation in the transfer form variables. We can safely conclude that multicollinearity is not an issue in our analysis. *The effect of forms on temporality* To understand which forms are most informative to distinguish between the patterns we focus on the parameter estimates. The estimated parameters measure the change in logarithmic odds of entrants or leavers against stayers associated with a unit change in the covariates. Since it is inconvenient to think in changes of logarithmic odds, we transform our estimated parameters $\hat{\alpha}_{1kj}$, where k is one of the 19 transfer forms, using the formula $e^{\hat{\alpha}_{1kj}} - 1$. As a result, we get the percentage change in the odds of being an entrant or leaver opposed to a stayer associated with a unit change in transfer forms holding the other forms constant. Due to this ceteris paribus effect, the relative differences in the graphs do not translate directly to the estimated parameters. The share of stayers that see a form as important is always larger than the share of entrants or leavers. This translates to negative coefficients for each transfer form since an increasing importance of a form is associated with a reduction in the odds of temporary relative to continuous relations. Yet, there are some positive estimates in table 4-5 suggesting that some transfer forms are associated with an increase in the odds of entrants or leavers against stayers. That is a direct result of holding the remaining set of transfer forms constant, which also partially fixes firm characteristics like size, resources, or preferences that themselves are informative about the transfer relations. Using all transfer forms as covariates partially purges this information from each transfer form variable which helps us to understand which forms are suited for entrants, leavers, or stayers independent of other firm characteristics. If we look at the first category of forms that are related to informal contacts and networks in model M0, we notice negative estimates but only two are significantly different from zero at a 10% significance level. A unit increase in the importance of academic publications is associated with a reduction in the odds of being an entrant versus being a stayer of 16.1% holding the importance of all other 18 forms constant. This implies that academic publications are significantly less frequently used by entrants than by stayers. We cannot claim the same thing for leavers. However, visiting conferences is associated with a reduction in their odds of 18.8%

against the stayers. The other informal transfer forms are uninformative to distinguish between entrants, leavers, and stayers. If we look at the second category of forms related to infrastructure, we observe that joint laboratories decrease the likelihood of leavers while infrastructure decreases the likelihood of entrants. The results suggest that a unit increase in the importance of laboratories is associated with an increase in the odds of entrants against stayers of 21.1%. A unit increase in the importance of infrastructure is associated with a decrease in the odds of entrants against stayers of 20.7%. Forms related to education and mobility show a mixed picture. Recruiting academic graduates for the R&D department and offering internships for R&D activities to students is significantly more important to continuous relations than temporary ones. Especially the recruiting of academic graduates is highly informative in distinguishing between transfer patterns and particularly so between entrants and stayers. The estimate suggest that a unit increase in the importance of recruiting is associated with a reduction in the odds of entrants against stayers of 26.4% while it is statistically significant at a 0.1% level. A rather surprising results emerges for joint dissertations. Although they are longer term relations that frequently last for 4 to 6 years and beyond, a unit increase in the importance of joint dissertations is associated with an increase in the odds of leavers against stayers by 36.1%. Contact of employed graduates with their laboratory at the university is significantly associated with the start of transfer activities and joint seminars seem to be more often associated with temporary relations than continuous ones, but only provide significant estimates at a 5% level for leavers. Further education offered by the universities also plays a significant role in the continuity of transfer activities. It reduces the odds of dropping out of the transfer process by around 21% and thus prolongs transfer activities. The fourth category includes three forms that relate to research activities. However, we observe significant effects only for research cooperation and research consortia. A unit increase in the importance of research cooperation is associated with a decrease in the odds of leavers against stayers of 37.7% and highly statistically significant. Contrasting that, the usage of research consortia with multiple academic and non-academic partners records positive coefficients that are significant at a 10% and 5% level. They imply that a unit increase in the importance of research consortia is associated with an increase in the odds of entrants or leavers against stayers of 26.7% or 38.3%, respectively. The last category of forms contains two single items related to academic consulting services. The estimates fail to be statistically significantly different from zero at a 10% level. These results suggest that consulting related transfer forms do not distinguish between the transfer status and are thus equally suitable for entrants, leavers, and stayers.

Table 4-5: Estimates of the multinomial logistic regression explaining transfer patterns

	(M0)		(M1)	
	Entrants	Leavers	Entrants	Leavers
		Forms		
I. Informal contacts & networks				
i. Informal	-0.140	-0.034	-0.179+	-0.051
	(0.099)	(0.100)	(0.108)	(0.105)
ii. Conferences	-0.052	-0.208+	0.091	-0.143
	(0.116)	(0.117)	(0.127)	(0.122)
iii. Publications	-0.175+	-0.096	-0.213+	-0.050
	(0.101)	(0.105)	(0.110)	(0.111)
II. Infrastructure				
i. Labs	0.159	-0.237+	0.182	-0.250+
	(0.118)	(0.129)	(0.131)	(0.135)
ii. Infrastructure	-0.232*	0.165	-0.240*	0.174
	(0.107)	(0.102)	(0.119)	(0.107)
III. Education & mobility				
i. Recruiting	-0.306***	-0.186*	-0.104	-0.056
	(0.089)	(0.091)	(0.102)	(0.098)
ii. Contacts to labs	0.219*	0.019	0.291*	0.048
	(0.111)	(0.114)	(0.120)	(0.117)
iii. Internships	-0.233*	-0.229*	-0.219+	-0.236*
	(0.103)	(0.105)	(0.112)	(0.108)
iv. Thesis	-0.091	-0.074	-0.047	-0.061
	(0.099)	(0.101)	(0.107)	(0.105)
v. Dissertations	0.112	0.308*	0.133	0.318*
	(0.129)	(0.130)	(0.138)	(0.135)
vi. Sabbaticals	-0.024	-0.200	-0.147	-0.263*
	(0.113)	(0.124)	(0.122)	(0.128)
vii. Seminars	0.198	0.252*	0.204	0.277*
	(0.125)	(0.128)	(0.138)	(0.132)
viii. Lectures	-0.002	-0.120	-0.002	-0.084
	(0.108)	(0.115)	(0.120)	(0.119)
ix. Further education	-0.163	-0.233*	-0.222*	-0.258*
	(0.103)	(0.106)	(0.112)	(0.110)
IV. Research				
i. Research cooperation	-0.114	-0.474***	0.012	-0.398**
	(0.108)	(0.122)	(0.120)	(0.127)
ii. Contract research	-0.163	-0.038	-0.061	0.018
	(0.149)	(0.161)	(0.164)	(0.169)
iii. Research consortia	0.237+	0.324*	0.259+	0.296+
	(0.138)	(0.148)	(0.149)	(0.151)
V. Consulting				
i. Expertise	0.013	0.075	-0.028	0.057
	(0.137)	(0.134)	(0.148)	(0.139)
ii. Consulting	-0.079	0.101	-0.034	0.087
	(0.136)	(0.136)	(0.147)	(0.140)

Estimates of the multinomial logistic regression explaining transfer patterns (ctd)

	(M0)		(M1)	
	Entrants	Leavers	Entrants	Leavers
`Firm-level controls`				
I. Firm characteristics				
i. ln(Employees + 1)			-0.119	0.181
			(0.117)	(0.110)
ii. Age			0.005*	-0.003
			(0.003)	(0.003)
iii. logit(Gross margin)			-0.170+	-0.012
			(0.097)	(0.094)
iv. Nearest university			-0.018*	-0.009
			(0.007)	(0.007)
v. ln(Employees w/ tertiary degree + 1)			-0.209*	-0.359***
			(0.103)	(0.098)
II. Innovation activities				
i. ln(R&D expenses + 1)			-0.063**	-0.044*
			(0.022)	(0.021)
ii. New products			-0.332	-0.085
			(0.270)	(0.261)
iii. Improved products			-0.566*	-0.270
			(0.276)	(0.262)
iv. Process innovations			-1.381***	-0.437*
			(0.221)	(0.211)
	(M0)		(M1)	
Observations	842		840	
Parameters	40		58	
χ^2_{2p}	154.7		295.2	
pseudo R^2	0.095		0.181	

+ p<0.1, * p<0.05, ** p<0.01, *** p<0.001

Note: This table shows the parameter estimates and the corresponding standard errors (in parentheses below) of our multinomial logistic regression explaining the choice of temporal transfer pattern. Our baseline choice is being a stayer. Each parameter estimate expresses the change in in the natural logarithm of the odds of a certain temporary transfer pattern against being a stayer associated with the respective variable. The specific temporary pattern is indicated above the column; *entrants* on the left and *leavers* on the right. We only use firms that used domestic transfer partners in at least one of two consecutive periods. We do not report the estimates of the intercept, as they are non-informative for our purposes. We use homoskedastic standard errors since they yield comparable estimates to clustered (on the sector level) or robust standard errors. To assess the model fit we report the number of observations used (Observation), the number of parameters in the model including the two intercepts (Parameters), the likelihood-ratio test statistic corresponding to the hypothesis that our estimated parameters excluding the intercepts are jointly insignificant (χ^2_{2p}), and finally McFadden's pesudo R^2.

Model M1

Answers to the research questions

Now that we know which forms are informative to distinguish between the three transfer patterns, we try to find out whether these differences exist because some forms are unattainable to firms with temporary relations due to lack of firm resources or whether they are unsuitable regardless. In line with model M1, we include the vector $\mathbf{x}_{it-6}$ in our set of covariates that covers the firm's financial and absorptive capacities. This allows us to answer our first research question (Q1) about the relation between a firm's resources and the temporal patterns of transfers. Furthermore, it allows us to have a grip on the second research question (Q2) whether forms have a direct relation to the temporality. If certain transfer forms still report significant coefficients, we know that they have discriminatory power independent of the included firm-level variables and are thus likely unsuited rather than unattainable for temporary relations. Table 4-5 shows the estimates under the header (M1). To see if the firm-level variables have additional explanatory power we test the hypothesis $\boldsymbol{\gamma}_{1,entrant} = \boldsymbol{\gamma}_{1,leaver} = 0$. A likelihood-ratio test clearly rejects the hypothesis (χ^2-statistic 295.2, p-value 3.3e-34) suggesting that the included firm-level covariates are indeed informative to distinguish between transfer patterns. This is also suggested by the increase in McFadden's pseudo R^2 of 0.086 compared to the baseline specification.

First research question: To answer it (Q1), we first look at the individual discriminatory power of x_{it-6}. The three indicator variables for innovation output have partial explanatory power. The coefficients on launching new products fails to be statistically significant at a 10% level. At a 5% significance level, we can also say that significantly improved products are less frequently found with entrants opposed to stayers and process innovations are less likely for both entrants and leavers. In terms of effect size, the presence of novel products reduces the odds of entrants against stayers by 43.2% while process innovations reduce the odds of entrants against stayers by 74.9% and those of leavers against stayers by 35.4%. A clear picture emerges from absorptive capacities measured by R&D expenses and the number of employees with a tertiary degree. All coefficients are negative and statistically significant at a 5% level and some even at 1% and .1% levels. A 1% increase in R&D expenses is associated with an approximate[20] decrease in the odds of entrants against stayers of 6 basis points (bp) while the odds of leavers against stayers fall by 4 bp. Similarly,

[20]The addition of 1 in the logarithmic transformation of the covariate explains the approximate nature of the statement. The marginal change in the odds from a 1% change in the covariate is calculated as $x = \left(e^{\beta * \ln(1+0.01)} - 1\right) * 100$.

a 1% increase in the number of employees with a tertiary degree approximately reduces the odds of entrants against stayers by 21 bp and of leavers against stayers by 37 bp.[21] This implies that firms with continuous relations have a significantly higher absorptive capacity. Or paraphrased, firms with temporary relations severely lack absorptive capacities. This is not surprising, as a lack of absorptive capacities affects the utility of external knowledge, which in turn reduces the incentives for firms to use a wide range of transfer forms as well as to maintain permanent transfer relationships. It is very likely that the underusage of forms by entrants and leavers opposed to stayers apparent in figure 4-4 is heavily influenced by this discrepancy. Transfer activities can incur high costs before potential returns are realised. The financial capacity of a firm is therefore a determining factor for the persistence of transfers and also has an influence on the choice of forms. Forms that cause high initial investments are ruled out for firms with low financial capacity. We measure this financial slack by the gross income which we approximate with the gross margin and the firm size.[22] Table 4-5 shows that firm size holds little explanatory power, although that may stem from a partial purging of scale effects by controlling for the number of employees with a tertiary degree, but the gross margin records a significant influence on the temporal transfer pattern. Enterprises with a higher gross margins are less likely to be entrants than stayers and that effect is significant at a 10% level. These results clearly show that a firm's resources and especially their absorptive capacities directly influence the temporality of transfer relationships. As such, we answer affirmatively to the first research question (Q1).

Second research question: Once we control for these differences in firm resources, we purge this information from the dependent variable such that the regressions inform about which forms are truly unsuited for temporary transfers. Comparing the coefficients on transfer forms between specification M0 and M1 of table 4-5 we hardly register any differences.[23] This shows that our previous results are mostly robust to the inclusion of firm-level variables. As evident by the variance inflation factors in column (M1) of table A.VII, including the firm-level controls affects the factors only mildly and we can again reject that multicollinearity biases our results. The estimates for forms related to informal contacts

[21] In addition, we examine how the predicted probabilities of the three transfer patterns change with the magnitude of the covariate. Figure A.II shows how the average predicted probabilities of entrants, leavers, and stayers change in our sample with a change in one of the continuous firm-level controls using start-of-period variables according to specification (M1).

[22] In the literature, firm size is often used as an indicator of the firm's financial capacities (Rajan & Zingales, 1998; T. Beck et al., 2005)

[23] We first note that almost all estimates keep their sign. Only 4 coefficients change their sign while the other 34 maintain it. Second, we note that 12 estimates retain their statistical significance at a 10% level, 3 loose it, and 2 gain it.

and networks are slightly different. Informal relations and academic publications seem unsuited for entrants. The estimates on forms related to infrastructure show no change. Using the universities' technical infrastructure seems unsuited for entrants and joint laboratories seem unsuited for leavers. These findings might reflect that entrants lack the tacit knowledge to use technical infrastructure in isolation. They favor joint laboratories where training, coaching and technical assistance are provided by the university. In the baseline specification recruiting is among the most informative transfer forms. Once we include the firm-level variables, this explanatory power is partly purged. As apparent in figure 3-3, recruiting graduates is heavily governed by a firm's absorptive capacity. Controlling for the absorptive capacity makes this transfer form a less significant predictor implying that recruiting is impeded by a lack of absorptive capacities. If firms have similar resources, recruiting is available to all firms irrespective of their temporal intentions. The other education and mobility related transfer forms are almost unaffected by the additional control variables. However, the coefficients are somewhat different overall, which underlines the general importance of absorptive capacity for the application of forms related to personnel mobility. Finally, one result is difficult to interpret. Despite its low resource requirements, further education, seem unsuited for temporary relations. Due to its apparent benefits to firms sales and innovation as shown by figure 3-3, it seems that firms with temporary relations could invest more heavily in further education. The research and consulting related forms also show no significant changes between the two models. Research cooperation remain to be unsuited for temporary relations and especially for leavers. However, research consortia are well suited and even more popular for firms with temporary opposed to continuous relations. Based on previous empirical research on a specific research consortium (Foray & Woerter, 2021), we note that research consortia do not require the same level of investment in sunk organizational capital as research cooperation. They can act as portals, providing access to more advantageous transfer relationships that promote the development of absorption capacity. This reduces transfer costs and increases benefits. They could be crucial portals to virtuous cycles. These results suggests that there is a direct relation (conditional on resources) between the choice of forms and the persistence of academic knowledge transfer. However, we cannot respond affirmatively to the second research question (Q2) with certainty. It might be that other unobserved firm characteristics confound that relation and that no direct relation is present. However, given the robustness tests, this is rather unlikely.

Policy-oriented sub-question (Q2a): Finally, we examine whether certain forms of intensive collaboration with low barriers to entry — in particular research consortia — enable

resource-constrained firms to establish lasting transfer relationships. Our estimates support this hypothesis, subject to certain caveats. Of the three research-related forms, research consortia are the only ones that occur more frequently among new entrants and leavers than among those who remain, and this positive relationship persists even after incorporating firm-level control variables into the model (M1). In contrast to research cooperation, consortia therefore do not appear to be the preserve of firms that already possess extensive absorption capacity and organisational capital. This is consistent with the view that they function as entry points — or portals — with low barriers to entry into academic knowledge transfer. However, our data do not allow for a complete assessment of the underlying mechanism, particularly as consortia are also strongly represented among "leavers". Consequently, we cannot rule out the possibility that they function more as a "revolving door" arrangement based on low levels of engagement than as a springboard to more intensive and lasting relationships. We therefore answer Question 2a in the affirmative, albeit with caution, and return to Section 5.2.

4.2.3 Robustness checks

Lagged firm-level controls The start-of-period firm-level controls in specification (M1) of table 4-5 contain values that are lagged by 6 years[24] or are partially imputed. It is a tradeoff between using variables that are not truly lagged by 6-years and the non-random loss of observations due to using true 6-year lags that is over-proportional for leavers and stayers but not entrants. Table A.VIII shows the estimates using observations with non-missing information on $\mathbf{x}_{it-6}$ after step 2 (true 6-year lags), step 4 (true lags but not necessarily 6-years) and step 5 (including imputations) outlined in section A.I.v The differences between these estimates are minor. There aren't any significant changes in the direction of the effects and the standard deviation of the coefficients for the different models (after step 2, after step 4 and after step 5) are particularly for entrants very small, indicating that they are very similar. The highest standard deviation between the coefficients of the different models shows conferences (0.233), followed by sabbaticals (0.170), expertise (0.135), labs (0.135), and contract research (0.123). The differences between the coefficients for entrants in the different models are below 0.120 for the rest of the transfer forms and indeed very small. There are also hardly any changes in the precision of the measurement. The differences in the coefficients between the models are slightly larger for leavers compared to entrants, but still minor. The standard deviation

[24] Between the second and third survey wave, we cover a period of 7 years. However, given the large distance between the survey waves this difference is negligible; like the robustness tests will show.

of the coefficients is greater than 0.1 for 11 forms, being 0.321 for dissertations, 0.243 for sabbaticals, and 0.2 for thesis. Like the category of entrants, there is little change in the precision of the measurement for the leavers. Overall, the imputation technique does not significantly change the results and thus has no significant influence on the observed associations.

Additional controls To strengthen the claims made in section 4.2.2, we include additional control variables that may confound the relation between transfer forms $\mathbf{f}_{it}$ and temporal transfer patterns tp^d_{it}. We build on the model M1 of table 4-5 that includes start-of-period firm-level variables $\mathbf{x}_{it-6}$. We consider the following models

$$\ln\left(\frac{P\left(tp^d_{it}=j\middle|\mathbf{X}_{it}\right)}{P\left(\mathrm{tp}^d_{it}=Stayer\middle|\mathbf{X}_{it}\right)}\right)=\dot{\gamma}_{0,j}+\mathbf{f}'_{it}\dot{\boldsymbol{\gamma}}_{1,j}+\mathbf{x}'_{it-6}\dot{\boldsymbol{\gamma}}_{2,j}+\mu_{s(i)t} \tag{M2.I}$$

$$\ln\left(\frac{P\left(tp^d_{it}=j\middle|\mathbf{X}_{it}\right)}{P\left(\mathrm{tp}^d_{it}=Stayer\middle|\mathbf{X}_{it}\right)}\right)=\ddot{\gamma}_{0,j}+\mathbf{f}'_{it}\ddot{\boldsymbol{\gamma}}_{1,j}+\mathbf{x}'_{it-6}\ddot{\boldsymbol{\gamma}}_{2,j}+\mu_{c(i)t} \tag{M2.II}$$

$$\ln\left(\frac{P\left(tp^d_{it}=j\middle|\mathbf{X}_{it}\right)}{P\left(\mathrm{tp}^d_{it}=Stayer\middle|\mathbf{X}_{it}\right)}\right)=\dddot{\gamma}_{0,j}+\mathbf{f}'_{it}\dddot{\boldsymbol{\gamma}}_{1,j}+\mathbf{x}'_{it-6}\dddot{\boldsymbol{\gamma}}_{2,j}+\mu_{s(i),j}+\mu_{c(i),j} \tag{M2.III}$$

$$\ln\left(\frac{P\left(tp^d_{it}=j\middle|\mathbf{X}_{it}\right)}{P\left(\mathrm{tp}^d_{it}=Stayer\middle|\mathbf{X}_{it}\right)}\right)=\ddddot{\gamma}_{0,j}+\mathbf{f}'_{it}\ddddot{\boldsymbol{\gamma}}_{1,j}+\mathbf{x}'_{it-6}\ddddot{\boldsymbol{\gamma}}_{2,j}+\mu_{t,j} \tag{M2.IV}$$

(M2.I) adds spatial dummies $\mu_{s(i),j}$ that capture fixed differences in transfer patterns by NUTS-III regions. (M2.II) adds sector dummies $\mu_{c(i),j}$ that capture fixed differences in transfer patterns NACE-II sectors. (M2.III) controls for both spatial and sector dummies. Finally, (M2.IV) uses period-fixed effects that are supposed to control for trends in temporal patterns that are useless since data limitations forbid the occurrence of entrants in the first survey wave and leavers in the last. Table A.IX contains the estimation results for these models. The last column shows that our key results are mostly robust to period fixed effects as well (see table A.IX, model (M2.IV)), but the other estimates in table A.IX would become shaky if we also would introduce period fixed effects. This is a direct result of our assignment mechanism. It is impossible that entrants are assigned to observations in the first survey period since we have not information on prior periods. Similarly, there are no observations in the last survey period that are assigned to leavers. This leads to perfect predictions of the odds of entrants against stayers by the first period dummy as well as the odds of leavers against stayers by the last period dummy. Associated with that is an increasing explanatory power of the model indicated by the increase in the McFadden's pseudo R^2; it jumps quite dramatically from 0.181 to 0.348. It also implies that the estimates become unreliable and hence we do not report any further specifications including temporal fixed effects. Since we cannot circumvent this issue with

our data, we must assume that time specific unobserved heterogeneity does not essentially bias our results. An indication of the plausibility of this assumption is provided by the results of model (M2.IV) in table A.IX compared to the results of the other models in table A.IX. There are hardly any systematic differences between the estimation results of these models. The estimates in the remaining columns (M2.I) to (M2.III) are rather unaffected by the additional covariates. The most significant effects are robust to any specification. Academic publications retain their negative coefficient on entrants and leavers and remains statistically significant at a 10% level for entrants irrespective of spatial or sector dummies.[25] This supports our claim that academic publications are an unsuited way to enter knowledge transfers. Infrastructure also remains a significant negative predictor of entrants against stayers at a 10% level until we include both spatial and sector dummies. The positive association between dissertations and leavers loses some significance if we include spatial dummies but the estimate remains significant at a level of at least 10% in all specifications. Most importantly, our findings regarding research related forms remain robust to all specifications. This strengthens our claim that research cooperations are unsuited for temporary relations while research consortia provide a valid alternative.

Assignment mechanisms As described in section 4.2.1 and in the section A.I.iii, some observations cannot be uniquely assigned to a transfer pattern. If the mechanism produces unjustified assignments, we wrongly infer that some forms are unsuited for a specific temporal transfer relation. To show how robust our estimates are we use the alternative assignment mechanisms summarized in table A.III. Table A.X shows the estimated parameters from model M1 using the three-level categorical dependent variables based on the three assignment mechanisms. The model fit in the baseline specification is remarkably equal across the three assignment mechanisms (baseline, reverse, double). Most significant effects exist irrespective of the assignment mechanism. The biggest discrepancy is between the baseline and the reversed assignment mechanism. Since they are two exact opposites for the observations - meaning that for instance leavers in the baseline assignment become entrants in the reverse assignment and vice versa - this is in line with our expectation. The most significant changes occur for research related transfers. The coefficient of cooperation is clearly lower for leavers in the reversed assignment since roughly a fifth are reassigned to stayers. The positive and significant coefficients on research consortia lose their significance, however the direction of the effects remain the

[25] Even in the most stringent specifications multicollinearity is not an issue. Between 37% and 69% of idiosyncratic variation is maintained even in the strictest specification using NACE-II and NUTS-III dummies.

same. Overall, the results show that our findings are robust to our assignment mechanisms.

Binary vs multinomial logistic model We can group the two temporary transfer patterns $tp_{it}^{d} \in \{Entrant, Leaver\}$ into one and compare it against continuous transfers $tp_{it}^{d} \in \{Stayer\}$. This approach helps us to determine whether a distinction between leavers and entrants increases our knowledge about transfer activities. In doing so, we can still assess whether there are path dependencies in some forms, i.e., that make entrants/leavers less likely. Furthermore, here we have no assigning problem. Table A.XI shows the estimated parameters from a binary logistic regression using the same set of independent variables as in model M1 but using the binary dependent variable.

$$\breve{tp}_{it}^{d} = \begin{cases} Temporary & , \ tp_{it}^{d} \in \{Entrant, Leaver\} \\ Continuous & , \ tp_{it}^{d} \in \{Stayer\} \end{cases}$$

We can confirm that the distinction between entrants, leavers, and stayers contributes to our understanding of the transfer behavior of firms. With the exemption of publications and infrastructure, a significant coefficient for entrants or leavers implies a significant coefficient in the binary equation. For example, contact to labs has a significantly positive coefficient for entrants and a positive but non-significant coefficient for leavers. The overall positive coefficient for contacts to labs in the binary equation refers to the effect on entrants and not on leavers. Similarly, we see for dissertations, sabbaticals, seminars, and research cooperation that the significant coefficient in the binary model is either driven by leavers or entrants but not both. A distinction between entrants and leavers thus brings much more clarity to the transfer behavior of firms.

5 Conclusion and discussion

Our study focused on the diversity of forms of knowledge transfer that are mobilized in the context of university–industry relations and on the strategies chosen by firms in this area. We explored the determinants of these choices and their effects. This investigation was based on three types of empirical observation and measurement:

- Each form of transfer is characterized by its *intensity*, which is measured by the financing and internal R&D capacities required to activate it and by its potential

benefits. We therefore observed high-intensity forms, low-intensity forms, and intermediate forms.

- Each firm has basic characteristics, including financial resources and internal R&D capacity.
- Each firm can be characterized by a temporal profile concerning its transfer activities. We observed firms that are continuously engaged (stayers), firms that interrupt their activity at certain times (leavers), and firms that are just starting out (entrants).

These observations and measurements are based on firm-level survey data from the Swiss Knowledge Transfer Survey (SKTS) spanning from 1999 to 2017 to investigate the forms of academic knowledge transfers used by firms as well as their temporality.

5.1 Summary of findings

As a first step, our descriptive results summarized in figure 4-4 show that firms using transfers temporarily select different forms than those that do so continuously. While entrants, leavers, and stayers heavily use informal contacts and networks, stayers rely on a broader set of forms including further tertiary education of their staff, recruiting graduates, research cooperation with universities and using their technical infrastructure, mobility of junior academic personnel via internships and thesis, or academic consulting. In line with our mapping of each form in the cost–benefit space apparent in figure 3-3, it is especially the costly forms like recruiting, thesis, industrial sabbaticals by senior academic staff, research cooperation, or contract research that are systematically underused by entrants and leavers opposed to stayers. Surprisingly, further education is also used less frequently by companies with temporary transfer relationships than by companies with continuous relationships, even though this transfer form requires only relatively low financial or absorption capacities.

In a second step, we use multinomial logistic regressions to provide a rigorous response to research questions Q1 and Q2.[26] Model M1 includes a comprehensive start-of-period control vector that includes a firm's financial and absorptive capacities. The estimates in table 4-5 show that entrants and leavers partially lack financial capacities and more severely lack absorptive capacities. As evident in figure 3-3 and backed by the literature as well as by figure 4-4, such limitations in capacities restrict their access to transfer forms

[26] Q1: Since the introduction of intensive partnerships depends on absorptive capacity, the question arises as to whether there is a link between a company's resources, particularly its absorptive capacity, and the continuity of KTT activities. Q2: Is there a direct link (conditional on resources) between the choice of forms and the continuity of KTT activities?

like research cooperation, recruiting graduates, industrial sabbaticals of senior academics, or joint laboratories with universities that provide the biggest benefits.

Furthermore, table 4-5 shows that even if firms have similar resources, forms are still predictive of temporality. Just to summarize a few findings which are of great interest from a policy point of view (below), further education lowers the odds of entrants and leavers (against stayers); research cooperation remains unsuited for temporary relations and especially for leavers; research consortia are well suited and even more popular for firms with temporary as opposed to continuous relations.

Some forms are simply unsuited for temporary relations, for example if they require a minimum level of absorptive capacities as well as the generation of trust, the establishment of inter-personal networks or the creation of specific communication codes — that is to say investments in "sunk organizational capital". Research cooperation is a typical case for this; a research consortium is not. It is an interesting opposition since both forms belong to the same category of transfer forms (research).

5.2 Policy discussion

Two things warrant special attention. First, although further education requires little financial and absorptive capacities, it seems to be underused by firms with temporary relations. What prohibits this uptake is not answered in this study. However, given the likely significant implications for turnover and innovation, particularly where further training in STEM subjects is concerned, it would be advisable to investigate the causes further and identify measures to promote such activities both in companies without continuous transfer and in academic faculties, which in many cases lack incentives to carry out such activities beyond their teaching and research projects.

Second, research consortia emerge as one of the most interesting transfer forms, particularly for entrants that lack the capacity to escape the "low-intensity-partnership trap", where they are limited to transfer forms that do not allow for the development of intangible assets needed for engaging in more beneficial transfer forms. Although research consortia require a certain degree of absorptive capacity from potential members, they are more prominent among entrants and leavers than among stayers. In line with Foray and Woerter (2021), we suspect that this is because participation in research consortia does not require significant investments in irreversible assets, such as investments in building social contacts with academia (see below). By contrast, research collaborations depend on investing in irreversible assets. Consortia are therefore particularly interesting for firms

that are less familiar with the academic world. Working with researchers who have strong industrial experience within the consortium can help to build social networks, trust and a shared understanding. This is a prerequisite for more intensive, longer-term transfer relationships.

Research consortia can therefore be a portal to more intensive transfer relationships for companies with temporary transfer relationships, particularly by promoting the development of absorptive capacity. This could initiate a virtuous (positive) cycle leading to more intensive, longer-term relationships. However, this does not come at no cost. While consortia do not require existing transfer relationships, a certain degree of absorptive capacity is necessary. Without this, firms would not be able to benefit from joint research efforts and build up sufficient intangible capital and absorptive capacity to take advantage of more intensive and beneficial forms of transfer such as research cooperation or joint laboratories. Higher absorptive capacities would enable access to these more advantageous forms and make them more cost-effective and beneficial. However, research consortia are currently also frequently used by leavers. This suggests that companies often fail to build up the intangible assets and absorption capacity needed to enter a positive cycle of more intensive forms of transfer and persistent relationships. Another, more positive conjecture about the consortium as a favoured form for leavers is that consortia also maintain an "organizational memory" about past relationships — leavers "are gone but not forgotten" — allowing firms to leave and re-enter at low cost.

This creates opportunities for innovation policy measures. Promoting research consortia as a portal for long-term transfer relationships must be accompanied by measures to develop sufficient absorption capacities, enabling companies to transition to more intensive forms of transfer. This would intensify transfer relationships and increase the importance of higher education institutions for the private sector, potentially reducing companies' R&D costs.

5.3 Limitations and further research

Our study has several limitations which qualify its conclusions and highlight areas for future research. Firstly, the analysis is confined to a single country. The Swiss innovation system exhibits distinctive characteristics, such as a strong public research base, a unique higher education landscape (ETH Domain, cantonal universities, etc.) and specific institutions designed to promote knowledge transfer. As a result, the correlations measured may not be transferable to other national contexts. Comparative or cross-national studies would

be required to establish external validity. Secondly, our results — as intended — are of an associative rather than a causal nature. Although we use (lagged) covariates at the start of the period, a comprehensive control vector, and spatial and sectoral fixed effects to mitigate confounding effects, we cannot rule out the possibility that unobserved firm characteristics — such as the quality of management, strategic orientation or pre-existing links to academia — may influence both the forms of engagement chosen by a firm and the durability of its commitment. The estimates should therefore be interpreted as robust conditional relationships. Thirdly, we cannot completely rule out slight measurement errors in the variables relating to the forms of transfer. These are captured using ordinal importance ratings provided by the firms themselves (which we dichotomise). Perceptual biases may therefore influence the results. Fourthly, the sample is potentially selective, particularly as participation in the surveys is voluntary. We only consider firms that take part in consecutive survey rounds. On average, these firms tend to be larger. Furthermore, survival bias and non-random attrition may influence the estimates. Finally, the data are organised into broad time periods, covering consecutive six-year intervals. This limits our ability to track fine-grained, path-dependent dynamics.

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A Appendix

A.I Background information

A.I.i Industry classification

Table A.I: Industries and their NACE equivalents

Industry	NACE	Description	Sample Share
1	10, 11, 12	Food / Beverages / Tobacco	4.8
2	13, 14, 15	Textiles / Clothing	1.3
3	16, 17	Wood / Paper	2.8
4	18	Printing	2.2
5	19, 22	Coke & Refined Oil / Rubber & Plastics	2.2
6	20	Chemicals	2.7
7	21	Pharmaceuticals	1.3
8	23	Non-metallic Minerals	1.7
9	24	Basic Metals	1.4
10	25	Fabricated Metals	7.5
11	26	Electronic & Optical Products	7.4
12	27	Electrical Equipment	2.7
13	28	Machinery	8.0
14	29, 30	Vehicles	0.9
15	31, 32	Other Manufacturing	3.2
16	33, 45	Repair & Installation	1.9
17	D, E	Energy / Water & Waste	2.6
18	41, 42	Construction & Civil Engineering	4.7
19	43	Specialized Construction	5.8
20	46, 47	Wholesale & Retail	8.0
21	H	Transportation & Storage	6.2
22	58, 59, 60	Publishing & Broadcasting	2.0
23	61, 62, 63, 95	Information & Communication Technology	1.4
24	K	Financial & Insurance Services	6.2
25	L, M w/o 71 & 72	Professional Services	3.3
26	71, 72	Technical & Scientific Services	4.6
27	I, N, 96	Other Services	3.2

Note: This table shows the composition of the 27 industries that build one of the strata dimensions of the KEP. The industries group NACE sections (I-digit) and divisions (II-digit) that yield a representative picture of the Swiss economy.

A.I.ii Swiss academic institutions

Table A.II: Higher education institutions in Switzerland

ETH

Swiss Federal Institute of Technology in Zurich (ETH Zurich)
Swiss Federal Institute of Technology in Lausanne (EPFL)
Paul Scherrer Institute (PSI)
Swiss Federal Institute of Aquatic Science and Technology (EAWAG)
Swiss Federal Laboratories for Materials Science and Technology (EMPA)
Swiss Federal Institute for Forest, Snow and Landscape Research (WSL)

Universities

University of Bern
University of Basel
University of Fribourg
University of Geneva
University of Lausanne
University of Lucerne
University of Neuchâtel
University of St. Gallen (HSG)
University of Italian Switzerland (USI)
University of Zurich

Universities of applied sciences

Bern University of Applied Sciences (BFH)
University of Applied Sciences Northwestern Switzerland (FHNW)
University of Applied Sciences Eastern Switzerland (FHO)
Lucerne University of Applied Sciences (HSLU)
University of Applied Sciences and Arts Western Switzerland (HES-SO)
University of Applied Sciences and Arts Southern Switzerland (SUPSI)
Zurich University of Applied Sciences (ZFH)

Note: University of Lucerne was only part of the most recent survey and is thus not part of the panel. This implies that all references made to universities as transfer partners are without any consideration of the University of Lucerne.

A.I.iii Temporal transfer patterns

Section 3.2.1 lays out our baseline assignment mechanism. As a robustness check, we consider two alternatives. The *reverse* mechanism gives precedence to abundance, such that stayers dominate entrants, which dominate leavers. It reads as

$$tp_{it} = \begin{cases} Entrant & \text{if } \mathfrak{d}_{it} = (0,1) \ \wedge \ \mathfrak{d}_{it+6} \neq (1,1) \\ Leaver & \text{if } \mathfrak{d}_{it+6} = (1,0) \wedge \ \mathfrak{d}_{it} \neq (1,1) \ \wedge \ \mathfrak{d}_{it} \neq (0,1) \\ Stayer & \text{if } \mathfrak{d}_{it} = (1,1) \ \vee \ \mathfrak{d}_{it+6} = (1,1) \end{cases}$$

based on transfer patterns $\mathfrak{d}_{it}$, or

$$tp_{it} = \begin{cases} Entrant & \text{if } d_{it} = 1 \ \wedge \ d_{it-6} = 0 \ \wedge \ d_{it+6} \neq 1 \\ Leaver & \text{if } d_{it} = 1 \ \wedge \ d_{it+6} = 0 \ \wedge \ d_{it-6} \neq 1 \ \wedge \ d_{it-6} \neq 0 \\ Stayer & \text{if } d_{it} = 1 \ \wedge \ (d_{it-6} = 1 \ \vee \ d_{it+6} = 1) \end{cases}$$

based on single-period transfers d_{it}. The *double* mechanism is non-unique: it assigns the 55 observations associated with distinct temporal patterns $\mathfrak{d}_{it} \neq \mathfrak{d}_{it+6}$ to both patterns by duplicating those observations and assigning one distinct pattern to each duplicate. Under this mechanism, the frequency of entrants and leavers aligns with the values reported in Table 3-1, whereas the frequency of stayers is almost twice as large, since every staying pattern is associated with two transfer-active observations, $d_{it-6} = 1$ and $d_{it} = 1$. It falls short of an exact duplication because firms that participate in all three waves and transfer throughout, i.e. $(d_{i2005}, d_{i2011}, d_{i2018}) = (1,1,1)$, record 3 instead of 4 observations with staying patterns; their frequency equals the discrepancy between a doubling of the values in Table 3-1 and the double section of Table 3-2. Table A.III lists all possible triples and their assignments under the three mechanisms.

A.I.iv Transfer forms

Table A.III: Transfer triplets and unique assignments

Triple	Couple	Assignment tp_{it}			Frequency		
$(d_{it-6}, d_{it}, d_{it+6})$	$(\mathfrak{d}_{it}, \mathfrak{d}_{it+6})$	Baseline	Reverse	Double	d_{it}	d^d_{it}	d^f_{it}
$(\varnothing, 1, 0)$	$(\varnothing, L)$	L	L	L	147	138	78
$(\varnothing, 1, 1)$	$(\varnothing, S)$	S	S	S	230	221	66
$(0, 1, \varnothing)$	$(E, \varnothing)$	E	E	E	168	162	66
$(0, 1, 0)$	(E, L)	L	E	*both*	19	18	7
$(0, 1, 1)$	(E, S)	E	S	*both*	20	19	8
$(1, 1, \varnothing)$	$(S, \varnothing)$	S	S	S	234	223	69
$(1, 1, 0)$	(S, L)	L	S	*both*	16	17	5
$(1, 1, 1)$	(S, S)	S	S	S	46	44	13
				$\sum$	880	842	312

Note: The assignment only applies to periods where firms have transfers, i.e. $d_{it} = 1$, and is undefined if they do not have transfers or we have no information on transfer, i.e. $tp_{it} \in \varnothing$ if $d_{it} \in \{0, \varnothing\}$. Most firms participate in two consecutive waves and not all waves naturally giving more mass to triples that feature a missing value $\varnothing$, i.e. $(\varnothing, 1, 0), (\varnothing, 1, 1), (0, 1, \varnothing)$ or $(1, 1, \varnothing)$. Missing values also occur in the first and last wave, i.e. if $t \in \{2005, 2018\}$, since we do not have information on transfers beyond the horizon from the start of 1999 and the end of 2017. We acknowledge that these missing values cloud the assignment of temporal patterns to single observations but stress that even with information on an infinite horizon the assignment problem remains since transfer active periods are associated with a couple of transfer patterns $(\mathfrak{d}_{it}, \mathfrak{d}_{it+6})$ that are distinct unless $\mathfrak{d}_{it} = \mathfrak{d}_{it+6} = S$. E stands for *Entrant*, L for *Leaver*, and S for *Stayer*. The different assignment mechanisms serve as a robustness check. The frequencies correspond to triples observed using foreign d^f_{it}, domestic d^d_{it} transfers, or both d_{it} as a base. The cumulative frequencies align with the baseline and reverse sections of table 3-2 while the double section counts the frequencies noted in the columns with distinct transfer patterns twice.

Table A.IV: Forms of knowledge and technology transfer

I. Informal contacts & networks	
i. Informal	Informal contacts with academic personnel for the exchange of information (e.g. by phone or mail)
ii. Conferences	Attendance at conferences, exhibitions, workshops etc. at higher education institutions
iii. Publications	Reading resp. citing of academic publications
II. Infrastructure	
i. Labs	Joint laboratories
ii. Infrastructure	Use of technical infrastructure of universities or public research centers
III. Education & mobility	
i. Recruiting	Employment of graduates from higher education institution in R&D
ii. Contacts to labs	Contact of hired graduates with their laboratory of their alma mater
iii. Internships	Participation of students/interns in R&D projects of our company
iv. Thesis	Awarding of theses in cooperation with higher education institutions
v. Dissertations	Awarding of dissertations in cooperation with higher education institutions
vi. Sabbaticals	Cooperation of academic scientists on R&D projects of our company (incl. "industrial sabbaticals")
vii. Seminars	Joint seminars/courses
viii.Lectures	Teaching assignment of employees of our company at higher education institutions
ix. Further education	Attendance of specialized further education courses (training programs) at higher education institutions by employees
IV. Research	
i. Research cooperation	Research projects in cooperation with higher education institutions (partly or completely financed by our company)
ii. Contract research	Longer-term research contracts with higher education institutions (contract research)
iii. Research consortia	Research consortia (with at least one participation from a higher education institution)
V. Consulting	
i. Expertise	Expert opinions from higher education institutions
ii. Consulting	Consulting services on the part of the higher education institutions

Note: The left column covers the acronyms per transfer form used throughout this paper to keep the notation as concise as possible. The wording of the right column and the headlines is identical to the questionnaires. The order of the transfer forms and their grouping under the given headlines is also identical to the survey. We measure each form on a 5-point rating scale where 1 indicates "no importance" and 5 indicates a "very high importance". All questions are formulated out of the perspective of a firm and targeted at knowledge and technology transfer activities with higher education institutions unless specified otherwise.

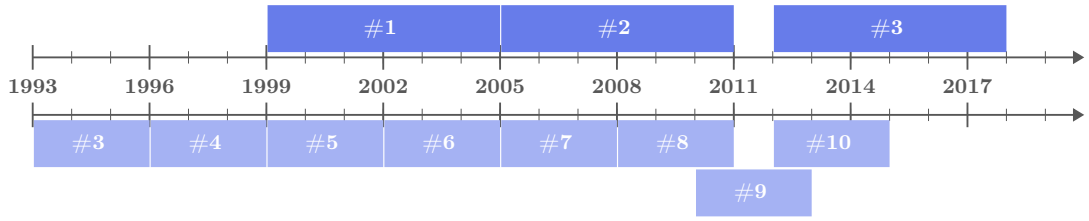
Table A.V: Pearson correlation coefficients of transfer forms $\mathbf{f}_{it}$

	i.	ii.	iii.	iv.	v.	vi.	vii.	viii.	ix.	x.	xi.	xii.	xiii.	xiv.	xv.	xvi.	xvii.	xviii.	xix.
Informal Contacts & Networks																			
i.	1.00																		
ii.	0.37	1.00																	
iii.	0.33	0.44	1.00																
Infrastructure																			
iv.	0.22	0.13	0.10	1.00															
v.	0.25	0.15	0.08	0.52	1.00														
Education & Mobility																			
vi.	0.27	0.21	0.20	0.25	0.29	1.00													
vii.	0.28	0.25	0.25	0.34	0.41	0.62	1.00												
viii.	0.18	0.16	0.15	0.31	0.34	0.52	0.47	1.00											
ix.	0.22	0.21	0.20	0.18	0.21	0.37	0.35	0.56	1.00										
x.	0.26	0.24	0.28	0.33	0.29	0.40	0.42	0.44	0.51	1.00									
xi.	0.24	0.15	0.13	0.28	0.37	0.34	0.34	0.41	0.36	0.44	1.00								
xii.	0.22	0.25	0.24	0.22	0.19	0.23	0.29	0.23	0.29	0.33	0.27	1.00							
xiii.	0.19	0.20	0.18	0.16	0.08	0.20	0.23	0.19	0.29	0.27	0.19	0.54	1.00						
xiv.	0.28	0.43	0.31	0.16	0.14	0.25	0.21	0.18	0.30	0.19	0.20	0.37	0.35	1.00					
Research																			
xv.	0.26	0.12	0.14	0.33	0.49	0.40	0.42	0.39	0.30	0.39	0.48	0.22	0.13	0.16	1.00				
xvi.	0.26	0.24	0.21	0.40	0.38	0.32	0.38	0.38	0.35	0.49	0.42	0.30	0.21	0.17	0.64	1.00			
xvii.	0.18	0.19	0.21	0.33	0.43	0.32	0.42	0.36	0.29	0.41	0.43	0.28	0.18	0.16	0.60	0.64	1.00		
Consulting																			
xviii.	0.24	0.20	0.24	0.21	0.28	0.13	0.24	0.20	0.26	0.29	0.32	0.28	0.18	0.30	0.30	0.36	0.29	1.00	
xix.	0.24	0.20	0.19	0.17	0.29	0.13	0.21	0.20	0.26	0.24	0.35	0.25	0.17	0.30	0.31	0.34	0.25	0.75	1.00

Note: We color coefficients as follows: [.2,.4], (.4,.6], (.6,.8]. The roman numerals correspond to the following transfer forms: [**Informal contacts & networks**] i. Informal, ii. Conferences, iii. Publications; [**Infrastructure**] iv. Labs, v. Infrastructure; [**Education & mobility**] vi. Recruiting, vii. Contacts to Labs, viii. Internships, ix. Thesis, x. Dissertation, xi. Sabbaticals, xii. Seminars, xiii. Lectures, xiv. Further Education; [**Research**] xv. Research Cooperation, xvi. Contract Research, xvii. Research Consortia; [**Consulting**] xviii. Expertise, xix. Consulting. We calculate the coefficients based on the 842 observations that have a domestic transfer pattern assigned, i.e., those with $tp^d_{it} \neq \varnothing$ as reported in table 3-2 and table A.III.

A.I.v Lagged firm-level variables

Figure A.I: Temporal coverage of all surveys



Note: The figure shows the temporal coverage of the SKTS and the SIDS. The SKTS contain variables measured over the last 6 years and the SIDS contain variables measured over the last 2 or 3 years. The continuous firm-level variables are end-of-period measurements while the binary firm-level variables are during-period measurements. For example, the 5th SIDS conducted in 2002 measures the full-time equivalents at the end of 2001 and the process innovator indicator based on if the firm had process innovations between the start of 2000 and the end of 2001.

To build the start-of-period firm-level variables $\mathbf{x}_{it-6}$ we require data lagged by 6 years. We cannot capture all lagged variables via the three waves of the Swiss Knowledge Transfer Survey (SKTS) that build the primary dataset for the analysis due to two reasons. First, we have an unbalanced panel and not all observations have a corresponding participation in the prior survey. Second, the first survey wave naturally lacks a predecessor that would contain lagged data. That is particularly problematic as it leads to an over-proportional drop in observations of leavers and stayers opposed to entrants since the latter do not occur in the first survey wave. This can lead to severely biased estimates since those observations are not missing at random. To retrieve the lagged variables, we also use waves of the Swiss Innovation and Digitalization Survey (SIDS), the Swiss equivalent of the Community Innovation Survey (CIS), that builds on the same sample of firms, the KOF Enterprise Panel (KEP). Figure A.I shows when the innovation surveys were conducted. The procedure to create the lagged variables is as follows

Step 1: Use the SKTS data lagged by 6 years[27]
Step 2: Use the SIDS data lagged by 6 years[28]
Step 3: Use the SIDS data lagged by 3 and 9 years and take averages[29]
Step 4: Use the SIDS data lagged by 12 years[30]
Step 5: Impute

The subsequent step only applies if the data cannot be retrieved by the former step. The imputation of the last step follows two approaches that follow the distribution of the

[27] In wave #3, we use x_{it-7}
[28] In wave #3, we use the average of x_{it-5} and x_{it-7}.
[29] In wave #3, we only use x_{it-3}
[30] In wave #3, we use x_{it-10}

variable within each transfer pattern $tp_{it}^{d} \in \{Entrants, Leavers, Stayers\}$. If the variable is binary, we construct 6 strata based on the end-of-period binary variable $x_{it} \in \{0, 1\}$ and the transfer pattern the observation belongs to. Within those strata we look at the distribution of the start-of-period variables $\mathbf{x}_{it-6}$ for observations in those strata that have their own historic data, i.e., where step 1 to step 4 is successful, and assign the lagged binary indicators randomly among the missing observations such that the strata maintain the same distribution, i.e., have the same share of innovators. If the variable is continuous, we construct the average inverse growth factor x_{it-6}/x_{it} for each transfer pattern and impute the lags by the end-of-period value multiplied by the average inverse growth factor of the corresponding transfer pattern. Since these inverse growth factors are highly variable across firms if based on levels, we use the share of full-time equivalents with tertiary degrees and R&D expenditures per turnover to impute and re-calculate the lagged levels by multiplying with the lagged full-time equivalents and turnover, respectively. 84 observations do not have prior participations in either the SKTS or SIDS and require imputation on all variables while 27 observations only require imputation on R&D expenditures but not on any other variables since they have prior participations.

Table A.VI: (Un)Availability of lagged variables

Before Step 1

	2005	2011	2018	∑
Entrant	0	94	87	181
Leaver	122	51	0	173
Stayer	189	204	95	488
∑	311	349	182	842

After Step 1

	2005	2011	2018	∑
Entrant	0	58	51	109
Leaver	122	30	0	152
Stayer	189	91	30	310
∑	311	179	81	571

After Step 2

	2005	2011	2018	∑
Entrant	0	58	47	105
Leaver	96	28	0	124
Stayer	149	84	23	256
∑	245	170	70	485

After Step 3

	2005	2011	2018	∑
Entrant	0	49	43	92
Leaver	64	21	0	85
Stayer	110	84	19	213
∑	174	154	62	390

After Step 4

	2005	2011	2018	∑
Entrant	0	26	23	49
Leaver	55	12	0	67
Stayer	100	38	10	148
∑	155	76	33	264

Note: This table shows the number of observations that have at least one missing lagged firm-level variable x_{it-6} after each step outlined in the text above. The observations are decomposed by temporal transfer pattern tp^{d}_{it} (rows) and survey wave (columns). Since we have no data on transfers $d_{i\tau}$ before 1999 and after 2018 there exist no entrants in the first survey wave and no leavers in the last survey wave. 42% of the observations have true x_{it-6} data and 67% have true historic data $x_{it-\tau}$ where $\tau \geq 3$.

Table A.VI shows the number of observations that miss at least one of the 8 lagged firm-level variables $\mathbf{x}_{it-6}$ after each step. In the first panel, we note that there are no entrants in the first survey wave and no leavers in the last survey wave. This is a consequence of the way we assign transfer patterns tp_{it} as described in section 3.2.1 and visible in table A.III and the limited data availability of transfer before 1999 or after 2018. We start out with 842 observations in need of lagged variables. In the second panel, the number of observations with missing values drops to 361. That means that 57% of all observations get their lagged variables from the prior SKTS, the most desirable data source. In the last survey, all observations get their lagged values this way since their assigned transfer pattern is based on the couple (d_{i2011}, d_{i2018}) implying that all of them participate in the second SKTS wave. 86% of the observations from the second wave get their lagged data from the first SKTS wave while the remaining 14% do not participate in that SKTS wave. As outlined above, we have no SKTS wave before 2005 and hence no observations from the first SKTS wave get their lags from step 1. This is especially problematic as this applies over-proportionally to leavers and stayers but not entrants. This may bias our estimates since those observations are not missing at random. We tackle this issue by using the alternative data from the SIDS which are based on the same panel of firms and conducted by the same institute. In the third panel, we see that using the SKTS and SIDS we get the true 6-year lags of 77% of the observations. Since the observations from the first survey wave are still missing frequently, we use other historic data from the SIDS in steps 3 and 4. In the fifth panel, we only miss lags on 13% of the observations while 87% get all lagged data from the firm's historic data. The last 13% comprise of 84 observations without prior participation in the SKTS or SIDS and 27 observations that participate but lack data on R&D expenditures. All those observations are imputed as outlined above. Although most observations get their start-of-period variables by true 6-year lags, we run robustness checks with data after step 2 (true 6-year lags from SKTS or SIDS) and step 4 (true 3-, 6-, 9-, or 12-year lags from SKTS or SIDS) to complement the results of model M1 in the main specification of table 4-5. The robustness checks are reported in table A.VIII.

A.II Predicted Probabilities

As additional information to the parameter estimates of the main regressions reported in table 4-5, we report the predicted probabilities of entrants, leavers, and stayers and their corresponding 95% confidence intervals over the sample support of each firm-level covariate. This gives a more graspable interpretation of the association between each firm-level variable and the temporal transfer patterns.

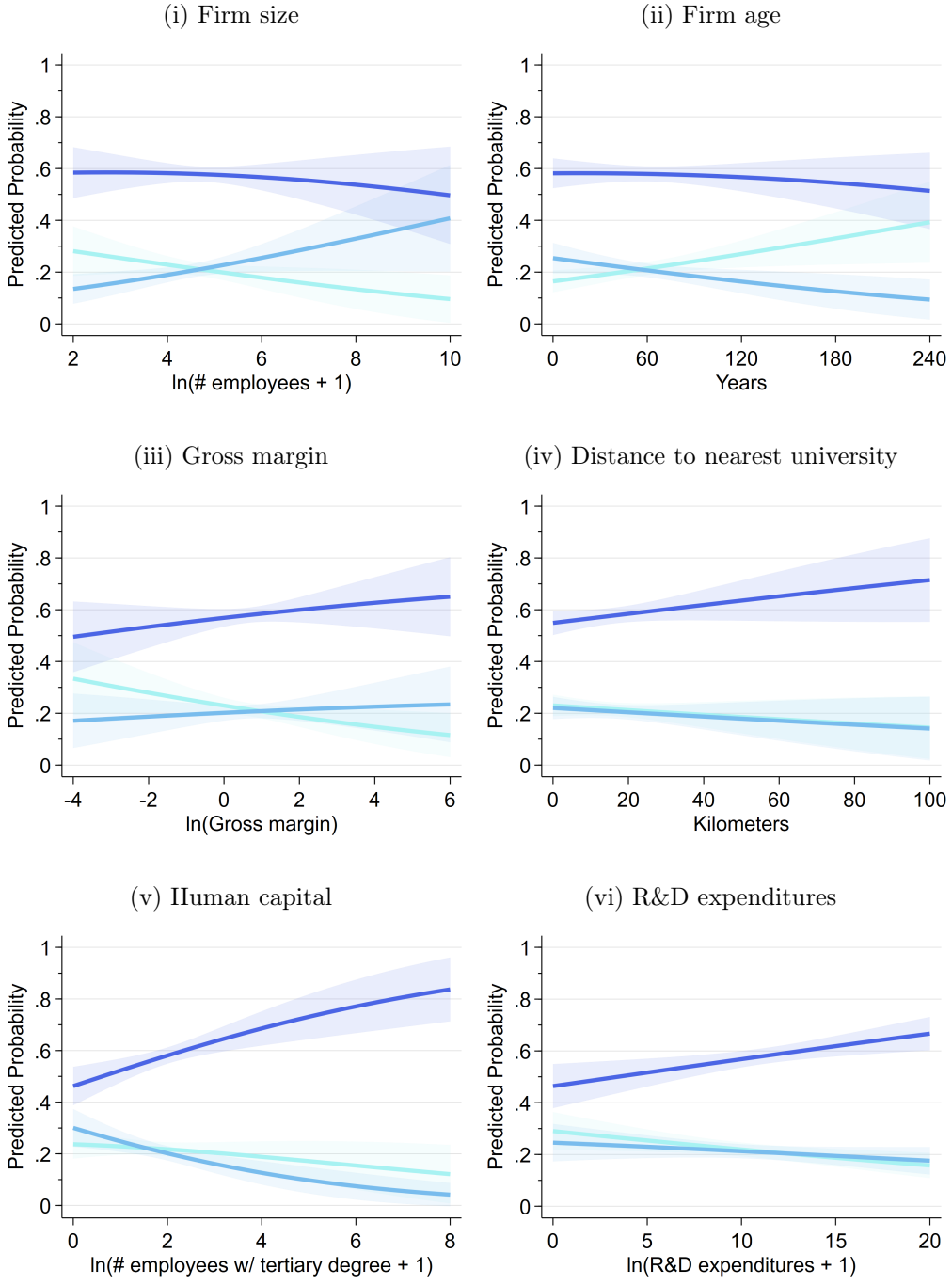
First, we note that the probability of stayers is always higher than those for entrants and leavers. This is due to the construction of our dependent variable and a direct outcome of the assignment mechanism described in section 3.2.1 and A.I.iii. Therefore, the change in the probabilities over the covariates matters and not the level.

Second, we note that firm size and age hardly affect the likelihood of stayers. On the contrary, the likelihood of entrants and leavers is affected by firm size and age in opposite directions. Entrants are more likely with decreasing firm size and particularly with increasing firm age. Leavers are more likely with increasing firm size and decreasing firm age. As such, entrants are mainly smaller and older firms while leavers are tendentially larger and younger.

Third, we note that an increasing distance to the nearest university is associated with an increasing likelihood of stayers and a decreasing likelihood of leavers and entrants. This implies that physical proximity matters to establish partnerships but not to maintain them.

Fourth, higher R&D expenditures and bigger human capital, which proxy the absorptive capacities of a firm, drastically raise the likelihood of continuous relations and reduce those of temporary relations. Human capital shows particularly strong effects and extreme values nearly reduce the likelihood of stayers to 1 and that of leavers to 0. This highlights the lack of absorptive capacity within entrants and leavers which poses strong barriers to extend their knowledge transfers to more engaged and impactful forms.

Figure A.II: Predicted probabilities over start-of-period firm-level variables $\mathbf{x}_{it-6}$



Note: This figure shows the predicted probabilities of **Entrants**, **Leavers**, and **Stayers** for a given covariate value. The line depicts the average predicted value in the estimation sample (i.e. the average prediction holding the respective covariate constant and using each observations remaining set of explanatory variables) and the shaded area shows the corresponding 95% confidence interval. The underlying model corresponds to (M1) in table 4-5 using start-of-period controls $\mathbf{x}_{it-6}$. We report only on continuous variables since discrete ones do not allow us to draw continuous functions.

A.III Robustness checks

A.III.i Multicollinearity

Table A.VII: Variance inflation factors

		(M0)	(M1)
I. Informal contacts & networks			
i.	Informal	1.37	1.40
ii.	Conferences	1.56	1.60
iii.	Publications	1.41	1.47
II. Infrastructure			
i.	Labs	1.55	1.57
ii.	Infrastructure	1.77	1.81
III. Education & mobility			
i.	Recruiting	1.94	2.21
ii.	Contacts to Labs	1.99	2.02
iii.	Internships	1.97	2.03
iv.	Thesis	1.79	1.84
v.	Dissertation	1.85	1.89
vi.	Sabbaticals	1.61	1.63
vii.	Seminars	1.65	1.67
viii.	Lectures	1.55	1.64
ix.	Further education	1.57	1.61
IV. Research			
i.	Research cooperation	2.31	2.40
ii.	Contract research	2.41	2.47
iii.	Research consortia	2.05	2.07
V. Consulting			
i.	Expertise	2.47	2.50
ii.	Consulting	2.45	2.47

Note: This table contains the variance inflation factors on each transfer form corresponding to the regression equation as indicated above the columns. It indicates how strong the linear relation is between the given transfer form and the remaining covariates. It is calculated as the reciprocal of the residual sum of squares from a linear regression of each transfer form on the remaining covariates. In the first column, the covariates are the remaining 18 transfer forms $\mathbf{f}_{it}$. In the second column, the covariates additionally include the start-of-period firm-level variables $\mathbf{x}_{it-6}$. All results show VIFs under 2.50 implying that at least 40% of the variation is unpurged by the other covariates. In line with table A.V, there is some positive correlation among the transfer forms, but multicollinearity is clearly not an issue in our analysis.

A.III.ii Lagged firm-level variables

Table A.VIII: Lagged firm-level variables

	After step 2		After step 4		After step 5	
	Entrants	Leavers	Entrants	Leavers	Entrants	Leavers
			Forms			
I. Informal contacts & networks						
i. Informal	-0.413*	0.208	-0.301*	0.016	-0.179+	-0.051
	(0.180)	(0.213)	(0.134)	(0.136)	(0.108)	(0.105)
ii. Conferences	0.521*	-0.295	0.151	-0.182	0.091	-0.143
	(0.210)	(0.227)	(0.151)	(0.152)	(0.127)	(0.122)
iii. Publications	-0.155	-0.325	-0.152	0.010	-0.213+	-0.050
	(0.196)	(0.220)	(0.138)	(0.145)	(0.110)	(0.111)
II. Infrastructure						
i. Labs	-0.060	-0.539*	0.111	-0.264	0.182	-0.250+
	(0.204)	(0.240)	(0.153)	(0.166)	(0.131)	(0.135)
ii. Infrastructure	-0.177	0.340+	-0.191	0.256+	-0.240*	0.174
	(0.176)	(0.193)	(0.140)	(0.135)	(0.119)	(0.107)
III. Education & mobility						
i. Recruiting	-0.294+	0.256	-0.145	0.186	-0.104	-0.056
	(0.175)	(0.191)	(0.125)	(0.125)	(0.102)	(0.098)
ii. Contacts to labs	0.421*	0.130	0.303*	0.002	0.291*	0.048
	(0.197)	(0.206)	(0.145)	(0.147)	(0.120)	(0.117)
iii. Internships	-0.154	-0.476*	-0.066	-0.364*	-0.219+	-0.236*
	(0.167)	(0.204)	(0.135)	(0.143)	(0.112)	(0.108)
iv. Thesis	-0.063	-0.439*	-0.065	-0.137	-0.047	-0.061
	(0.166)	(0.208)	(0.128)	(0.136)	(0.107)	(0.105)
v. Dissertations	0.228	0.915***	0.135	0.410*	0.133	0.318*
	(0.218)	(0.265)	(0.163)	(0.172)	(0.138)	(0.135)
vi. Sabbaticals	0.184	0.222	-0.047	-0.043	-0.147	-0.263*
	(0.187)	(0.209)	(0.145)	(0.158)	(0.122)	(0.128)
vii. Seminars	0.022	-0.043	0.100	0.192	0.204	0.277*
	(0.249)	(0.283)	(0.176)	(0.173)	(0.138)	(0.132)
viii. Lectures	0.201	0.068	0.022	-0.057	-0.002	-0.084
	(0.200)	(0.258)	(0.157)	(0.172)	(0.120)	(0.119)
ix. Further education	-0.183	-0.097	-0.247+	-0.320*	-0.222*	-0.258*
	(0.174)	(0.207)	(0.132)	(0.140)	(0.112)	(0.110)
IV. Research						
i. Research cooperation	-0.043	-0.670**	-0.038	-0.468**	0.012	-0.398**
	(0.193)	(0.251)	(0.146)	(0.164)	(0.120)	(0.127)
ii. Contract research	-0.138	0.007	-0.301	0.085	-0.061	0.018
	(0.268)	(0.274)	(0.201)	(0.203)	(0.164)	(0.169)
iii. Research consortia	0.316	0.368	0.432*	0.274	0.259+	0.296+
	(0.243)	(0.260)	(0.178)	(0.185)	(0.149)	(0.151)
V. Consulting						
i. Expertise	0.225	-0.057	0.180	-0.047	-0.028	0.057
	(0.236)	(0.242)	(0.175)	(0.168)	(0.148)	(0.139)
ii. Consulting	-0.392+	0.003	-0.189	0.165	-0.034	0.087
	(0.229)	(0.238)	(0.179)	(0.169)	(0.147)	(0.140)

Lagged firm-level variables (ctd.)

	After step 2		After step 4		After step 5	
	Entrants	Leavers	Entrants	Leavers	Entrants	Leavers
`Firm-level controls`						
I. Firm characteristics						
i. ln(Employees + 1)	-0.052	0.593**	-0.084	0.441**	-0.119	0.181
	(0.199)	(0.224)	(0.145)	(0.145)	(0.117)	(0.110)
ii. Age	0.002	-0.002	0.004	-0.001	0.005*	-0.003
	(0.005)	(0.005)	(0.003)	(0.003)	(0.003)	(0.003)
iii. logit(Gross Margin)	-0.275	-0.134	-0.152	0.002	-0.170+	-0.012
	(0.174)	(0.209)	(0.124)	(0.131)	(0.097)	(0.094)
iv. Nearest university	-0.021+	-0.006	-0.013	-0.002	-0.018*	-0.009
	(0.011)	(0.014)	(0.009)	(0.009)	(0.007)	(0.007)
v. ln(Employees tert. + 1)	-0.375*	-0.476*	-0.200	-0.531***	-0.209*	-0.359***
	(0.176)	(0.191)	(0.128)	(0.129)	(0.103)	(0.098)
II. Innovation Activity						
i. ln(R&D expenses + 1)	-0.093*	-0.065	-0.081**	-0.074**	-0.063**	-0.044*
	(0.039)	(0.048)	(0.026)	(0.027)	(0.022)	(0.021)
ii. New products	0.058	-0.026	0.072	0.055	-0.332	-0.085
	(0.477)	(0.569)	(0.350)	(0.367)	(0.270)	(0.261)
iii. Improved products	-0.423	-0.572	-0.705*	-0.274	-0.566*	-0.270
	(0.477)	(0.542)	(0.357)	(0.367)	(0.276)	(0.262)
iv. Process innovations	-1.145***	0.356	-1.340***	-0.272	-1.381***	-0.437*
	(0.333)	(0.419)	(0.260)	(0.272)	(0.221)	(0.211)

	After step 2	After step 4	After step 5
Observations	357	578	840
Parameters	58	58	58
χ^2_{2p}	138.483	211.525	295.204
pseudo R^2	0.220	0.191	0.181

+ p<0.1, * p<0.05, ** p<0.01, *** p<0.001

Note: This table shows the parameter estimates and the corresponding standard errors (in parentheses below) of specification (M1) in table 4-5 using start-of-period firm-level controls according to the steps outlined in table A.VI. The last two columns, after step 5, are the same as in table 4-5. The first two columns, after step 2, use observations that have true $\mathbf{x}_{it-6}$ values from SKTS or SIDS. The second two columns, after step 4, use observations that have true $\mathbf{x}_{it-\tau}$ $\tau \geq 3$ values from SKTS or SIDS.

A.III.iii Additional Controls

Table A.IX: Multinomial logistic regression using spatial, sector and period-fixed effects

	(M1)		(M2.I)		(M2.II)		(M2.III)		(M2.IV)	
	Entrants	Leavers	Entrants	Leavers	Entrants	Leavers	Entrants	Leavers	Entrants	Leavers
					Forms					
I. Informal contacts & networks										
i. Informal	-0.179+	-0.051	-0.138	-0.026	-0.196+	-0.065	-0.153	-0.043	-0.230+	-0.048
	(0.108)	(0.105)	(0.113)	(0.109)	(0.112)	(0.110)	(0.117)	(0.115)	(0.122)	(0.111)
ii. Conferences	0.091	-0.143	0.036	-0.208+	0.093	-0.159	0.048	-0.201	0.088	-0.077
	(0.127)	(0.122)	(0.133)	(0.126)	(0.134)	(0.129)	(0.140)	(0.134)	(0.143)	(0.129)
iii. Publications	-0.213+	-0.050	-0.194+	-0.042	-0.238*	-0.056	-0.193	-0.047	-0.085	-0.223+
	(0.110)	(0.111)	(0.115)	(0.115)	(0.114)	(0.114)	(0.119)	(0.119)	(0.125)	(0.119)
II. Infrastructure										
i. Labs	0.182	-0.250+	0.190	-0.251+	0.159	-0.349*	0.165	-0.366*	0.095	-0.146
	(0.131)	(0.135)	(0.137)	(0.139)	(0.139)	(0.141)	(0.146)	(0.145)	(0.141)	(0.144)
ii. Infrastructure	-0.240*	0.174	-0.221+	0.179	-0.235+	0.236*	-0.219+	0.237*	-0.255*	0.195+
	(0.119)	(0.107)	(0.122)	(0.110)	(0.125)	(0.114)	(0.129)	(0.117)	(0.128)	(0.114)
III. Education & mobility										
i. Recruiting	-0.104	-0.056	-0.073	-0.040	-0.083	0.038	-0.048	0.052	-0.133	-0.023
	(0.102)	(0.098)	(0.104)	(0.100)	(0.107)	(0.106)	(0.110)	(0.108)	(0.116)	(0.104)
ii. Contacts to labs	0.291*	0.048	0.232+	0.041	0.305*	0.070	0.251+	0.060	0.352**	-0.007
	(0.120)	(0.117)	(0.126)	(0.120)	(0.125)	(0.124)	(0.132)	(0.127)	(0.135)	(0.126)
iii. Internships	-0.219+	-0.236*	-0.264*	-0.273*	-0.244*	-0.295**	-0.282*	-0.332**	-0.215+	-0.241*
	(0.112)	(0.108)	(0.116)	(0.111)	(0.118)	(0.114)	(0.122)	(0.117)	(0.124)	(0.115)
iv. Thesis	-0.047	-0.061	0.041	0.022	-0.038	-0.038	0.039	0.037	-0.054	-0.071
	(0.107)	(0.105)	(0.115)	(0.111)	(0.112)	(0.111)	(0.119)	(0.116)	(0.120)	(0.111)
v. Dissertations	0.133	0.318*	0.077	0.262+	0.179	0.303*	0.104	0.245+	0.088	0.326*
	(0.138)	(0.135)	(0.144)	(0.140)	(0.145)	(0.142)	(0.151)	(0.148)	(0.155)	(0.144)
vi. Sabbaticals	-0.147	-0.263*	-0.126	-0.242+	-0.204	-0.293*	-0.189	-0.290*	-0.047	-0.324*
	(0.122)	(0.128)	(0.126)	(0.132)	(0.127)	(0.134)	(0.132)	(0.140)	(0.138)	(0.138)
vii. Seminars	0.204	0.277*	0.149	0.237+	0.194	0.226	0.146	0.198	0.137	0.328*
	(0.138)	(0.132)	(0.143)	(0.136)	(0.144)	(0.140)	(0.150)	(0.144)	(0.156)	(0.139)
viii. Lectures	-0.002	-0.084	-0.010	-0.066	0.022	-0.039	-0.002	-0.015	0.055	-0.107
	(0.120)	(0.119)	(0.125)	(0.123)	(0.126)	(0.125)	(0.131)	(0.130)	(0.135)	(0.125)
ix. Further education	-0.222*	-0.258*	-0.177	-0.209+	-0.195	-0.244*	-0.154	-0.195	-0.219+	-0.315**
	(0.112)	(0.110)	(0.116)	(0.113)	(0.119)	(0.117)	(0.124)	(0.122)	(0.124)	(0.120)
IV. Research										
i. Research cooperation	0.012	-0.398**	0.018	-0.410**	-0.029	-0.439**	0.001	-0.436**	0.025	-0.421**
	(0.120)	(0.127)	(0.123)	(0.130)	(0.128)	(0.134)	(0.132)	(0.137)	(0.128)	(0.137)
ii. Contract research	-0.061	0.018	-0.168	-0.020	-0.100	0.011	-0.201	-0.026	-0.123	0.050
	(0.164)	(0.169)	(0.173)	(0.174)	(0.171)	(0.176)	(0.181)	(0.181)	(0.188)	(0.171)
iii. Research consortia	0.259+	0.296+	0.294+	0.292+	0.341*	0.385*	0.377*	0.368*	0.248	0.314*
	(0.149)	(0.151)	(0.158)	(0.156)	(0.157)	(0.160)	(0.166)	(0.165)	(0.162)	(0.158)
V. Consulting										
i. Expertise	-0.028	0.057	-0.112	0.023	-0.018	0.079	-0.106	0.053	-0.017	0.048
	(0.148)	(0.139)	(0.156)	(0.146)	(0.152)	(0.147)	(0.162)	(0.154)	(0.160)	(0.147)
ii. Consulting	-0.034	0.087	0.039	0.125	-0.015	0.100	0.056	0.131	0.050	0.017
	(0.147)	(0.140)	(0.152)	(0.143)	(0.151)	(0.147)	(0.156)	(0.150)	(0.160)	(0.148)

Multinomial logistic regression using spatial, sector and period-fixed effects (ctd.)

	(M1)		(M2.I)		(M2.II)		(M2.III)		(M2.IV)	
	Entrants	Leavers	Entrants	Leavers	Entrants	Leavers	Entrants	Leavers	Entrants	Leavers
					Firm-level controls					
I. Firm characteristics										
i. ln(Employees + 1)	-0.119	0.181	-0.077	0.233*	-0.232+	0.055	-0.178	0.123	-0.024	0.099
	(0.117)	(0.110)	(0.125)	(0.116)	(0.132)	(0.129)	(0.141)	(0.136)	(0.136)	(0.116)
ii. Age	0.005*	-0.003	0.006*	-0.003	0.004	-0.006*	0.006+	-0.007*	0.003	-0.000
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
iii. logit(Gross Margin)	-0.170+	-0.012	-0.129	0.015	-0.138	0.153	-0.129	0.193	-0.071	-0.116
	(0.097)	(0.094)	(0.102)	(0.098)	(0.122)	(0.118)	(0.127)	(0.123)	(0.111)	(0.104)
iv. Nearest university	-0.018*	-0.009	-0.020+	-0.018	-0.020*	-0.009	-0.021	-0.017	-0.021**	-0.008
	(0.007)	(0.007)	(0.012)	(0.011)	(0.008)	(0.007)	(0.013)	(0.012)	(0.008)	(0.007)
v. ln(Employees tert. + 1)	-0.209*	-0.359***	-0.262*	-0.423***	-0.108	-0.266*	-0.181	-0.324**	-0.290**	-0.265*
	(0.103)	(0.098)	(0.108)	(0.104)	(0.121)	(0.112)	(0.127)	(0.119)	(0.112)	(0.108)
II. Innovation Activity										
i. ln(R&D expenses + 1)	-0.063**	-0.044*	-0.059**	-0.040+	-0.072**	-0.050*	-0.073**	-0.048*	-0.059*	-0.050*
	(0.022)	(0.021)	(0.022)	(0.022)	(0.023)	(0.023)	(0.024)	(0.024)	(0.024)	(0.023)
ii. New products	-0.332	-0.085	-0.322	-0.117	-0.455	-0.290	-0.419	-0.333	-0.340	-0.039
	(0.270)	(0.261)	(0.279)	(0.269)	(0.284)	(0.281)	(0.292)	(0.290)	(0.312)	(0.274)
iii. Improved products	-0.566*	-0.270	-0.537+	-0.258	-0.528+	-0.078	-0.542+	-0.117	-0.412	-0.398
	(0.276)	(0.262)	(0.284)	(0.271)	(0.287)	(0.279)	(0.296)	(0.290)	(0.319)	(0.275)
iv. Process innovations	-1.381***	-0.437*	-1.433***	-0.329	-1.411***	-0.400+	-1.477***	-0.302	-1.285***	-0.619**
	(0.221)	(0.211)	(0.237)	(0.223)	(0.232)	(0.223)	(0.250)	(0.236)	(0.245)	(0.229)
Fixed effects										
NUTS-III			✓	✓			✓	✓		
NACE-II					✓	✓	✓	✓		
Period									✓	✓
	(M1)		(M2.I)		(M2.II)		(M2.III)		(M2.IV)	
Observations	840		840		840		840		840	
Parameters	58		98		106		146		64	
χ^2_{2p}	295.204		341.458		356.233		401.867		568.128	
pseudo R^2	0.181		0.209		0.218		0.246		0.348	

+ p<0.1, * p<0.05, ** p<0.01, *** p<0.001

Note: The table reports the estimates from regressions (M2.I) to (M2.IV) laid out in section 4.2.3. The spatial fixed effects $\mu_{s(i),j}$ include 19 NUTS-III (cantons) dummies. We group smaller cantons (AI/AR, GL/SZ, OW/NW/UR, SH/TG and JU/BE) to prevent perfect or near perfect prediction due to small or empty cells of some canton-pattern combinations. The sector fixed effects $\mu_{c(i),j}$ include 23 NACE-II dummies. We group some divisions with their closest relative, mostly neighboring divisions, to prevent perfect or near perfect prediction. Due to the construction and assignment of our temporal transfer patterns it is technically impossible for entrants to exist in the first survey period and leavers in last. Using period fixed effects, this leads to perfect prediction of these cells and associated true coefficients of minus infinity. Stata corrects for this by assuming that the coefficients are associated with a p-value of 1 such that the null-hypothesis of any effect is never rejected rather than dropping the associated variable. This results in highly distorted estimates as is apparent in column (M2.IV). Since we cannot circumvent this issue, we cannot include time trends in our regressions and must assume that the uncovered relations are stable over time. Our baseline choice is being a stayer. Each parameter estimate expresses the change in the natural logarithm of the odds of a certain temporary transfer pattern against being a stayer associated with the respective variable. The specific temporary pattern is indicated above the column; *entrants* on the left and *leavers* on the right. We only use firms that used domestic transfer partners in at least one of two consecutive periods. We do not report the estimates of the intercept, as they are non-informative for our purposes. We use homoskedastic standard errors since they yield comparable estimates to clustered (on the sector level) or robust standard errors. To assess the model fit we report the number of observations used (Observation), the number of parameters in the model including the two intercepts (Parameters), the likelihood-ratio test statistic corresponding to the hypothesis that our estimated parameters excluding the intercepts are jointly insignificant (χ^2_{2p}), and McFadden's pseudo R^2.

A.III.iv Assignment mechanism

Table A.X: The influence of different assignment mechanisms

	(M1) Baseline		(M1) Reverse		(M1) Double	
	Entrants	Leavers	Entrants	Leavers	Entrants	Leavers
			Forms			
I. Informal contacts & networks						
i. Informal	-0.179+	-0.051	-0.129	-0.120	-0.139	-0.038
	(0.108)	(0.105)	(0.107)	(0.111)	(0.102)	(0.102)
ii. Conferences	0.091	-0.143	0.032	-0.082	0.053	-0.140
	(0.127)	(0.122)	(0.126)	(0.130)	(0.120)	(0.119)
iii. Publications	-0.213+	-0.050	-0.196+	0.055	-0.218*	-0.033
	(0.110)	(0.111)	(0.111)	(0.118)	(0.106)	(0.108)
II. Infrastructure						
i. Labs	0.182	-0.250+	0.255+	-0.123	0.182	-0.200
	(0.131)	(0.135)	(0.132)	(0.144)	(0.125)	(0.133)
ii. Infrastructure	-0.240*	0.174	-0.292*	0.080	-0.243*	0.118
	(0.119)	(0.107)	(0.119)	(0.113)	(0.111)	(0.104)
III. Education & mobility						
i. Recruiting	-0.104	-0.056	-0.123	-0.160	-0.125	-0.072
	(0.102)	(0.098)	(0.102)	(0.106)	(0.096)	(0.096)
ii. Contacts to labs	0.291*	0.048	0.255*	0.015	0.280*	0.024
	(0.120)	(0.117)	(0.120)	(0.127)	(0.114)	(0.114)
iii. Internships	-0.219+	-0.236*	-0.135	-0.147	-0.163	-0.188+
	(0.112)	(0.108)	(0.111)	(0.115)	(0.107)	(0.106)
iv. Thesis	-0.047	-0.061	-0.047	0.026	-0.060	-0.046
	(0.107)	(0.105)	(0.107)	(0.111)	(0.102)	(0.103)
v. Dissertations	0.133	0.318*	0.121	0.231	0.124	0.291*
	(0.138)	(0.135)	(0.138)	(0.143)	(0.132)	(0.132)
vi. Sabbaticals	-0.147	-0.263*	-0.120	-0.339*	-0.077	-0.241+
	(0.122)	(0.128)	(0.123)	(0.140)	(0.116)	(0.126)
vii. Seminars	0.204	0.277*	0.216	0.304*	0.178	0.264*
	(0.138)	(0.132)	(0.140)	(0.138)	(0.133)	(0.129)
viii. Lectures	-0.002	-0.084	-0.028	-0.125	0.005	-0.081
	(0.120)	(0.119)	(0.121)	(0.127)	(0.114)	(0.116)
ix. Further education	-0.222*	-0.258*	-0.316**	-0.258*	-0.251*	-0.255*
	(0.112)	(0.110)	(0.112)	(0.116)	(0.107)	(0.108)
IV. Research						
i. Research cooperation	0.012	-0.398**	0.006	-0.230+	-0.019	-0.350**
	(0.120)	(0.127)	(0.120)	(0.133)	(0.115)	(0.124)
ii. Contract research	-0.061	0.018	-0.120	-0.028	-0.059	0.013
	(0.164)	(0.169)	(0.170)	(0.182)	(0.159)	(0.165)
iii. Research consortia	0.259+	0.296+	0.222	0.213	0.228	0.261+
	(0.149)	(0.151)	(0.151)	(0.163)	(0.142)	(0.146)
V. Consulting						
i. Expertise	-0.028	0.057	0.060	-0.043	0.064	0.048
	(0.148)	(0.139)	(0.147)	(0.149)	(0.139)	(0.136)
ii. Consulting	-0.034	0.087	-0.068	0.167	-0.083	0.083
	(0.147)	(0.140)	(0.148)	(0.149)	(0.140)	(0.137)

The influence of different assignment mechanisms (ctd.)

	(M1) Baseline		(M1) Reverse		(M1) Double	
	Entrants	Leavers	Entrants	Leavers	Entrants	Leavers
`Firm-level controls`						
I. Firm characteristics						
i. ln(Employees + 1)	-0.119	0.181	-0.101	0.180	-0.094	0.175
	(0.117)	(0.110)	(0.116)	(0.117)	(0.111)	(0.109)
ii. Age	0.005*	-0.003	0.004	-0.004	0.004	-0.004
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
iii. logit(Gross Margin)	-0.170+	-0.012	-0.099	0.029	-0.113	0.017
	(0.097)	(0.094)	(0.095)	(0.098)	(0.091)	(0.092)
iv. Nearest university	-0.018*	-0.009	-0.016*	-0.004	-0.016*	-0.007
	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)
v. ln(Employees tert. + 1)	-0.209*	-0.359***	-0.217*	-0.329**	-0.222*	-0.344***
	(0.103)	(0.098)	(0.102)	(0.104)	(0.099)	(0.097)
II. Innovation Activity						
i. ln(R&D expenses + 1)	-0.063**	-0.044*	-0.063**	-0.039+	-0.061**	-0.040+
	(0.022)	(0.021)	(0.021)	(0.022)	(0.020)	(0.021)
ii. New products	-0.332	-0.085	-0.340	-0.156	-0.329	-0.100
	(0.270)	(0.261)	(0.268)	(0.278)	(0.257)	(0.257)
iii. Improved products	-0.566*	-0.270	-0.572*	-0.232	-0.518+	-0.237
	(0.276)	(0.262)	(0.276)	(0.280)	(0.264)	(0.258)
iv. Process innovations	-1.381***	-0.437*	-1.295***	-0.399+	-1.251***	-0.335
	(0.221)	(0.211)	(0.220)	(0.223)	(0.211)	(0.208)

	(M1) Baseline	(M1) Reverse	(M1) Double
Observations	840	840	894
Parameters	58	58	58
χ^2_{2p}	295.204	274.851	288.015
pseudo R^2	0.181	0.177	0.167

+ p<0.1, * p<0.05, ** p<0.01, *** p<0.001

Note: The table reports the influence on the estimated parameters using the different assignment mechanisms described in section 3.2.1 and documented in table A.III. The baseline (precedence to scarcity) and reverse assignment (precedence to abundance) have the same number of observations while the double assignment records an increase of 54 observations. Using table A.III, we note that those are the 18 observations with $\left(d^d_{it-6}, d^d_{it}, d^d_{it+6}\right) = (0,1,0)$, the 19 observations with $\left(d^d_{it-6}, d^d_{it}, d^d_{it+6}\right) = (0,1,1)$ and the 17 observations with $\left(d^d_{it-6}, d^d_{it}, d^d_{it+6}\right) = (1,1,0)$, hence those patterns where the column *Double* states *both*. It is exactly those 54 observations that change their assigned temporal patterns with the different assignment mechanisms. Only 11% of all observations are affected by the different assignment.

A.III.v Binary logit

Table A.XI: Binary vs multinomial logit

	(M1) Binary	(M1) Multinomial	
	Temporary	Entrants	Leavers
`Forms`			
I. Informal contacts & networks			
i. Informal	-0.113	-0.179+	-0.051
	(0.087)	(0.108)	(0.105)
ii. Conferences	-0.029	0.091	-0.143
	(0.102)	(0.127)	(0.122)
iii. Publications	-0.135	-0.213+	-0.050
	(0.090)	(0.110)	(0.111)
II. Infrastructure			
i. Labs	-0.031	0.182	-0.250+
	(0.105)	(0.131)	(0.135)
ii. Infrastructure	-0.024	-0.240*	0.174
	(0.090)	(0.119)	(0.107)
III. Education & mobility			
i. Recruiting	-0.075	-0.104	-0.056
	(0.081)	(0.102)	(0.098)
ii. Contacts to labs	0.157+	0.291*	0.048
	(0.095)	(0.120)	(0.117)
iii. Internships	-0.220*	-0.219+	-0.236*
	(0.089)	(0.112)	(0.108)
iv. Thesis	-0.062	-0.047	-0.061
	(0.087)	(0.107)	(0.105)
v. Dissertations	0.213+	0.133	0.318*
	(0.109)	(0.138)	(0.135)
vi. Sabbaticals	-0.194*	-0.147	-0.263*
	(0.098)	(0.122)	(0.128)
vii. Seminars	0.248*	0.204	0.277*
	(0.111)	(0.138)	(0.132)
viii. Lectures	-0.043	-0.002	-0.084
	(0.097)	(0.120)	(0.119)
ix. Further education	-0.244**	-0.222*	-0.258*
	(0.091)	(0.112)	(0.110)
IV. Research			
i. Research cooperation	-0.187+	0.012	-0.398**
	(0.097)	(0.120)	(0.127)
ii. Contract research	-0.032	-0.061	0.018
	(0.131)	(0.164)	(0.169)
iii. Research consortia	0.267*	0.259+	0.296+
	(0.120)	(0.149)	(0.151)
V. Consulting			
i. Expertise	0.022	-0.028	0.057
	(0.118)	(0.148)	(0.139)
ii. Consulting	0.035	-0.034	0.087
	(0.118)	(0.147)	(0.140)

Binary vs multinomial logit (ctd.)

	(M1) Binary	(M1) Multinomial	
	Temporary	Entrants	Leavers
`Firm-level controls`			
I. Firm characteristics			
i. ln(Employees + 1)	0.033	-0.119	0.181
	(0.093)	(0.117)	(0.110)
ii. Age	0.001	0.005*	-0.003
	(0.002)	(0.003)	(0.003)
iii. logit(Gross Margin)	-0.089	-0.170+	-0.012
	(0.079)	(0.097)	(0.094)
iv. Nearest university	-0.013*	-0.018*	-0.009
	(0.006)	(0.007)	(0.007)
v. ln(Employees tert. + 1)	-0.274***	-0.209*	-0.359***
	(0.082)	(0.103)	(0.098)
II. Innovation Activity			
i. ln(R&D expenses + 1)	-0.053**	-0.063**	-0.044*
	(0.018)	(0.022)	(0.021)
ii. New products	-0.213	-0.332	-0.085
	(0.215)	(0.270)	(0.261)
iii. Improved products	-0.424*	-0.566*	-0.270
	(0.216)	(0.276)	(0.262)
iv. Process innovations	-0.882***	-1.381***	-0.437*
	(0.172)	(0.221)	(0.211)
	(M1) Binary	(M1) Multinomial	
Observations	840	840	
Parameters	29	58	
χ^2_{2p}	226.732	295.204	
pseudo R^2	0.198	0.181	

+ p<0.1, * p<0.05, ** p<0.01, *** p<0.001

Note: This table shows the parameter estimates from equation (M1) of section 4.2.1 that uses start-of-period firm-level control variables $\mathbf{x}_{it-6}$ with different dependent variables and hence different estimation methods. The first column on the left uses a binary dependent variable $\breve{tp}^d_{it} \in \{0,1\}$ that measures if a firm has temporary or continuous transfer relations and stems from a logistic regression. It is derived from the 3-level categorical variable tp^d_{it} and takes the value 1 if $tp^d_{it} \in \{Entrant, Leaver\}$ and 0 if $tp^d_{it} \in \{Stayer\}$. The two columns on the right are those reported in table 4-5 and stem from multinomial logistic regressions. We report this table to judge if a distinction of temporary relations into entrants and leavers is worthwhile. Based on the χ^2 test and the pseudo R^2 both models provide a similar fit and we can reject that a drastic loss of power is the cost paid by using the asymmetry of temporary relations. The benefits are evident by looking at the estimated parameters. While the estimates from the multinomial logistic regression are in line with those from the binary logistic regression the former provide more nuanced and useful insights regarding whether the parameters are homogeneous or heterogeneous among the two temporary transfer patterns. This is also apparent by the goodness of fit tests we conduct in section 4.2.2 that clearly reject the hypothesis $\boldsymbol{\beta}_{0,Entrant} = \boldsymbol{\beta}_{0,Leaver}$.