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Commercializing University Research in Transition Economies: Technology Transfer Offices or Direct Industrial Funding?

Abstract

There is a paucity of knowledge on research commercialization by university scientists worldwide. The objective of this paper is to identify the role that Technology Transfer Offices (TTOs) and direct Industrial Funding play in university research commercialization in transition economies of Azerbaijan, Belarus and Kazakhstan during 2015-2017. We do this by developing a novel database and a multi-level model which explains how individual attributes, organizational and ecosystem characteristics explain the extent of knowledge commercialization .

We apply the generalized Heckman approach to account for two selection biases, reducing the sample from 2,602 to 272 scientists, and further use a mixed-method approach to analyse 27 face-to-face interviews with researchers and TTO managers. The results demonstrate that research commercialization is not associated with the existence and awareness of TTO or the establishment of commercialization contracts via TTO, but the direct industrial funding of university research. Taken together the findings have clear implications for scholars, scientific entrepreneurs, TTOs and investors who aim to exploit university knowledge in transition economies.

KEYWORDS

Technology Transfer Offices, Industry funding, knowledge spillover, knowledge transfer, academic entrepreneurship, transition

1. Introduction

The role of contemporary universities has become multifaceted (Etzkowitz et al. 2000; Bishop et al., 2011; Perkmann et al. 2011a, 2013; Hvide and Jones, 2016) and encompasses teaching, research and entrepreneurship function (Audretsch, 2014). Universities implement far-reaching changes to become more entrepreneurial (Mets, 2009; Siegel and Wright, 2015; Cunningham and Link, 2015; Díez-Vial and Montoro-Sánchez, 2016) and technology transfer processes are being set up to promote research commercialisation (Lockett et al., 2003; Lockett and Wright, 2005; Phan and Siegel, 2006). Research commercialization requires building a strong external partnership with ecosystem stakeholders (Bogler, 1994; Bozeman and Gaughan, 2007; Bekkers and Freitas, 2008; Miller et al. 2014; Acs et al. 2017) such as entrepreneurs, universities, local and national government , private industry.

The financial returns from and mechanisms of university knowledge transfers have remained under researched and have triggered an interest across entrepreneurship scholars and policy makers

39 in developed countries (Chapple et al., 2005; Wright et al. 2006; Kenney and Patton, 2009; Kalar
40 and Antoncic, 2015; Abreu et al. 2016) and developing countries (Sedaitis, 2000; Varblane et al.
41 2007a, 2007b; Bajmócy et al. 2010; Marozau and Guerrero, 2016; Guerrero and Urbano, 2017).

42 Responding to public research commercialization opportunities, universities have explored a
43 number of models of university knowledge transfer with entrepreneurship centres, university
44 incubators, science parks and TTOs performing a role of a conduit (Link et al. 2007; Siegel et al.
45 2003, 2007; Wright et al. 2008; Kenney and Patton, 2009; Muscio, 2010; O’Kane et al. 2015;
46 Kolympiris and Klein, 2017).

47 Although substantial research in the field of academic entrepreneurship has been conducted
48 in developed economies (Siegel et al. 2003, 2004; Powers and Mcdougall, 2005; Phan and Siegel,
49 2006; Perkmann et al. 2011a, 2011b; Ankrah and al-Tabbaa, 2015; Mosey et al. 2017), the field
50 remains fragmented and incomplete in transition economies (Varblane et al. 2007a, 2007b; Marozau
51 and Guerrero, 2016). Empirical evidence of how knowledge spills at universities and reaches
52 industry is very limited in these countries (Radosevic, 1998; Kwiek, 2012; Leydesdorff et al. 2015;
53 Huyghe et al. 2016).

54 There is a lack of relevant data on the mechanisms of knowledge transfer from universities,
55 regulation, incentives, culture and the external investment in research (Tchalakov et al. 2010).
56 While the TTOs remains a new phenomenon, direct industrial funding has demonstrated its strength
57 as a conduit of university knowledge transfer (Boardman and Ponomariov, 2009; Czarnitzki et al.
58 2015, 2016). Direct industrial funding is defined as industry’s direct financial support for the
59 development of technology by a university scientist(s). To the best of our knowledge, no research
60 to date has established and empirically tested the role that university TTO and direct industrial
61 funding play in research commercialization by scientists in transition economies (Grimaldi et al.
62 2011; Bradley et al. 2013; Guerrero et al. 2016; Theodoraki and Messeghem, 2017). This study
63 bridges the gap.

64 Adopting the TTO perspective of the knowledge spillover theory of entrepreneurship

65 (KSTE) in organizations (Acs et al. 2013; Shu et al. 2014) and the stakeholder perspective to
66 entrepreneurship ecosystem framework (Grimaldi et al. 2011; Miller et al. 2014), we respond to the
67 call in academic entrepreneurship literature (Aldridge and Audretsch, 2011; Perkmann et al. 2011a,
68 2011b, 2013; Siegal and Wright, 2015; Mosey et al. 2017) and entrepreneurship ecosystem
69 literature (Acs et al. 2014; 2017) - to investigate research commercialization in transition
70 economies, while accounting for a broad range of individual, organizational and ecosystem level
71 characteristics (Link and Siegel, 2005; Boardman and Ponomariov, 2009; Kenney and Patton, 2009;
72 Stam and Spiegel, 2017). These characteristics include professional level attributes such as amount
73 of local and international publications, position, workload, research sponsorship, TTO collaboration
74 and awareness as well as organizational level characteristics (university ownership, availability of
75 TTO, contract relationship with TTO) and ecosystem level characteristics related to scientist's
76 research funding by government, private industry in a home country and abroad, affiliated
77 university, foreign universities or institutions, non-for-profits, other public organizations).

78 We start with the premise that there is a substantial variation in traditional and alternative
79 models of university technology transfer (Siegel et al., 2003, 2004; Kenney and Goe, 2004; Bradley
80 et al. 2013), that governs scientist's decision-making on research commercialization (Kenney and
81 Patton, 2009).

82 We use the unique primary data on 2,602 scientists collected by online survey in Belarus,
83 Kazakhstan and Azerbaijan between November 2015 and August 2017. Having applied for two
84 potential selection bias corrections: one for commercialization income disclosure and another for
85 commercialization activity, our final model consists of 272 scientists. Belarus, Kazakhstan and
86 Azerbaijan are representative transition economies with substantial research commercialization
87 activity, with residents and non-residents currently hold 2503 (Belarus), 3218 (Kazakhstan) and 345
88 (Azerbaijan) World Intellectual Property Organization (WIPO) active patents (WIPO, 2018).

89 We validate our empirical findings with a mixed-method analysis of 27 face-to-face
90 interviews with researchers and TTO managers during April 2016 – September 2017. A mixed

91 method approach was demanded, because we had a compelling reason to suspect that measuring
92 and analysing the commercialization of university research by relying solely upon data collected by
93 the TTOs (Aldridge and Audretsch, 2011) or universities (Caldera and Debande, 2010) may lead to
94 a systematic underestimation of knowledge transfers.

95 Taken together our results suggest that TTO activity neither impede nor facilitate research
96 commercialization by scientists, while direct industrial funding stands as an efficient conduit for
97 research commercialization. Although most scientists expressed their support to the “Professor
98 Privilege” –type system (Hvide and Jones, 2016), vesting ownership with the inventor (Kenney and
99 Patton, 2009) may take years in the troubled transition context.

100 The next section introduces the theoretical framework and formulates the research
101 hypotheses. Section 3 describes the data and methodology. Section 4 describes results. Section 5
102 discusses the paper’s main findings and section 6 concludes.

103

104 **2. Background Literature**

105 **2.1 Knowledge transfers from universities to industry**

106 Over the years, several scholars have studied the process of transferring knowledge from
107 universities (Gulbrandsen and Smeby, 2005; Grimaldi et al. 2011; Aldridge and Audretsch, 2011;
108 Freitas et al. 2013; Díez-Vial and Montoro-Sánchez, 2016; Guerrero et al. 2016) which could be
109 either intentional (knowledge transfer) or unintentional (knowledge spillover) (Audretsch et al.
110 2005; Audretsch and Keilbach, 2009). Prior research identified stakeholders that facilitate
111 knowledge adoption and commercialization such as TTO, and the channels of commercialization,
112 such as licencing technology (Bradley et al. 2013) and university spin-offs, that represent one of the
113 most visible forms of knowledge transfer (Di Gregorio and Shane 2003; Lockett et al. 2003). Even
114 though the knowledge transfer is often formalized (Siegel et al. 2003, 2004), the role of scientists in
115 the knowledge transfer is not obvious (van Looy et al. 2004; Grimaldi et al. 2011). The term
116 scientist is used as a descriptor for a university researcher.

117 As in any entrepreneurial process, there are individual, organizational and contextual filters
 118 that limit the knowledge transfer and prevent a complete transformation of knowledge into
 119 economically viable products (Acs et al. 2013; Guerrero and Urbano, 2014; Shu et al. 2014). The
 120 economics of entrepreneurship allows us to understand the main environmental factors that
 121 influence the organizational filters (Guerrero and Urbano 2012, 2014; Miller et al. 2014), while the
 122 KSTE explains the role of regional, organizational and individual characteristics in the knowledge
 123 transfer (Kenney and Goe, 2004; Guerrero and Urbano 2014; Urbano and Guerrero, 2013; Shu et al.
 124 2014). The “Bayh-Dole” Act and “Professor Privilege” system are often used as an example to
 125 explain how individual, organizational and contextual filters could be effectively leveraged so that
 126 knowledge transfer takes place between scientists and industry (Perkmann and Walsh, 2010;
 127 Grimaldi et al. 2011; Aldridge and Audretsch 2011; Hvide, and Jones, 2016).

128 Unlike European economies (Wright et al. 2007, 2008), transition and developing
 129 economies have never experienced neither “Bayh-Dole”-type regulation in the US (So et al. 2008;
 130 Korosteleva and Belitski, 2017) nor “Professor Privilege –type system in Germany (Czarnitzki et al.
 131 2015) and Norway (Hvide and Jones, 2016). Studies seeking to explain knowledge transfer from a
 132 university using the KSTE at the organizational and individual levels (Audretsch et al. 2005; Acs et
 133 al. 2013; Guerrero and Urbano, 2014) have identified a number of internal (organisational) and
 134 external (environmental) factors that either facilitate or impede the process of knowledge transfer.
 135 One important factor is the establishment of a university TTO (Siegel and Wessner, 2012; Siegel
 136 and Wright, 2015) and engagement with private industry (Clarysse and Moray 2004; Boardman and
 137 Ponomariov, 2009; Clarysse et al. 2011; Díez-Vial and Montoro-Sánchez, 2016). The differences
 138 between the traditional KSTE and a TTO perspective of the KSTE are described in Table 1 using
 139 Shu’s et al. (2014) classification criteria.

140
 141 Table 1. A TTO perspective of the knowledge spillover theory of entrepreneurship

	Traditional KSTE framework	KSTE in TTOs
Empirical existence	National and regional levels (Acs et al. 2013, 2014; Audretsch, 2014)	Organizational level (Shu et al. 2014) with an individual perspective of the KSTE (Guerrero and Urbano, 2014) and

		university perspective (Audretsch et al. 2005; Audretsch and Keilbach, 2009)
Theoretical bases	Endogenous growth theory (Arrow, 1962) KSTE in various contexts (e.g. university, region, city) (Audretsch et al. 2005; Shu et al. 2014)	Entrepreneurship ecosystem theory (Stam, 2015; Stam and Spigel, 2017), the evolution of technology transfer competencies at universities (Clarysse et al. 2011; Ankrah and Al-Tabbaa, 2015)
Contextual factors	Regional level and entrepreneurship environment (Kenney and Patton, 2005; Agarwal et al. 2010)	University entrepreneurial orientation (Aldridge and Audretsch, 2011; Grimaldi et al. 2011; Kalar and Antoncic, 2015)
Knowledge filters	Formal and informal institutions (risk aversion of stakeholders, legal restrictions, bureaucracy, labour market rigidities, taxes, and lack of cognition and trust) (Agarwal et al. 2010; Shu et al. 2014)	Knowledge management and commercialization (Audretsch, 2014).
Knowledge spillovers	Investment in knowledge, collaboration and labour mobility (Acs et al 2013), creativity (Audretsch and Belitski, 2013)	Knowledge transfer and knowledge spillover from the university to ecosystem stakeholders (Grimaldi et al. 2011; Guerrero and Urbano, 2014)
Relationship between knowledge filters and spillovers	Indirect (Agarwal et al. 2010; Acs et al. 2013)	Indirect (Acs et al. 2013)
Consequences	Entrepreneurial performance is measured at regional or national levels (new business start-ups, survival, quality of entrepreneurship, high growth)	Commercialization income of a scientist and/or TTO

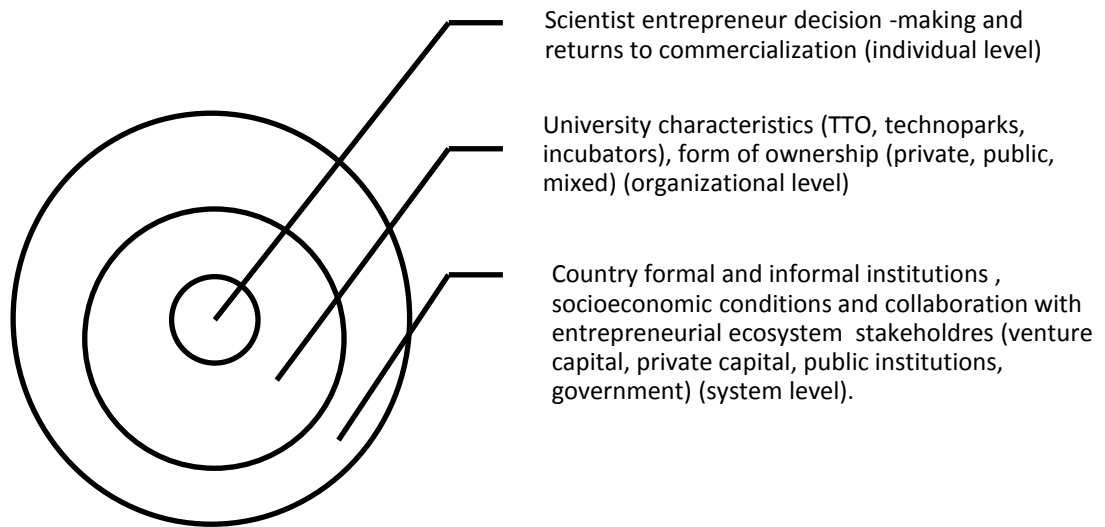
142 Source: Authors with criteria adopted from Shu et al (2014)

143

144

145 **2.2. Determinants of knowledge commercialization: a multilevel model**

146 The process of research commercialization is a multi-level and involves interactions between
147 an individual researcher, a university and the external environment (Powers and McDougall 2005;
148 Guerrero and Urbano, 2014; Theodoraki and Messeghem, 2017). Freitas et al. (2013) distinguish
149 two modes of interaction: the institutional mode, which involves interactions between the university
150 and ecosystem stakeholders (industry, government, non-for-profit, angel investors); and the
151 personal contractual mode, which is a formal and informal collaboration between ecosystem
152 stakeholders and scientists, carried out with or without the direct involvement of a university.
153 Building on Freitas et al. (2013), Grimaldi et al. (2011), Perkmann et al. (2011a, 2013) and
154 Guerrero and Urbano (2014), Figure 1 illustrates a three-level model of university research
155 commercialization, which connects scientist's behaviour, organizational structures and ecosystem
156 environment factors (Aldridge and Audretsch, 2011).



158

159 Figure 1: Multi-level model of university research commercialization

160

161 The first (system/ecosystem) level of analysis focuses on the business and socioeconomic
 162 environment (Cooke et al., 1997; Stam, 2015; Audretsch and Belitski, 2017; MIT REAP, 2017).
 163 National innovation activity, intellectual property (IP) and other institutional reforms (So et al.
 164 2008), the role that policy makers can have in the university's commercialization activities (Florida
 165 and Kenney 1988) and the variety of entrepreneurship ecosystem stakeholders either support or
 166 impede research commercialization. According to existing literature on entrepreneurial ecosystems
 167 the presence of stakeholders facilitates entrepreneurial decision-making (Audretsch et al. 2005;
 168 Audretsch, 2014; Ankrah and Al-Tabbaa, 2015; Stam, 2015). When the entrepreneurial ecosystem
 169 context is conducive, scientists at universities will leverage available resources and information via
 170 engagement with ecosystem stakeholders to transfer and commercialize new knowledge (Perkmann
 171 and Walsh, 2010; Acs et al., 2017). This creates strong links between scientists and university
 172 TTOs, where the invention is initially disclosed as well as between university and industry, where
 173 the invention is adopted and commercialized. Once the invention has been disclosed, TTOs will
 174 decide whether or not to further commercialize it (acquire a patent, discuss commercial potential

175 the prospective users, market technology, negotiate licencing agreements, licence technology)
176 (Cooke et al., 1997; Siegel et al. 2004; Link and Siegel, 2005; Shu et al., 2014). For this reason, the
177 theoretical framework used to study the interaction between a university and ecosystem
178 stakeholders, builds on the TTO's perspective of the KSTE.

179 In contrast, an entrepreneurship ecosystem with weak institutional context works in the
180 opposite fashion (Wright et al., 2006, 2008). Below are the few examples. First, instead of
181 disclosing the information to TTOs, which will later market the technology to organizations and
182 entrepreneurs, providing revenues to the university, scientists will choose directly interact with
183 private companies bypassing the university administration and TTOs (Thursby and Thursby, 2004).
184 To access the extent of the alternative modes of research commercialization it is necessary to study
185 the individual level data, measuring the relationship between scientist's behaviour and individual
186 commercialization income. Second, as the invention has never been disclosed, the TTO will not be
187 able to market it to entrepreneurs and organizations, will not negotiate the licence and not sign the
188 licencing agreement. For this reason, the theoretical framework used to study the interaction
189 between a scientist and ecosystem stakeholders, builds on the stakeholders' perspective to
190 entrepreneurship ecosystem framework (Grimaldi et al. 2011; Miller et al. 2014; Stam, 2015; MIT
191 REAP, 2017; Acs et al. 2014, 2017; Audretsch and Belitski, 2017). The literature distinguishes
192 between five potential groups of ecosystem stakeholders who may be involved in university
193 research commercialization: entrepreneurs, risk capital providers, universities (TTOs), policy
194 makers (government) and large corporations (private industry).

195 The second (organizational) level of analysis focuses on universities and their ownership, the
196 administrative structures within them that support research commercialization (TTOs, academic
197 departments, techno parks, incubators) (Carayol and Matt, 2004; Audretsch et al., 2005; Dasgupta
198 and David, 1994; Guerrero et al., 2016). The university level explains the efforts by university
199 TTOs to seek out new commercialization opportunities (Siegel et al., 2004, 2007; Clarysse et al.,
200 2004, 2011), facilitate early evaluation of IP rights strategies, exploit infrastructure, stimulate

201 specific venture initiatives and spin-offs (Kenney and Patton, 2005; Wright et al., 2007, 2009), and
202 attract public and private funds (Degroof and Roberts, 2004; Wright et al. 2009; Mosey et al. 2017).

203 Several successful initiatives to support academic and student entrepreneurship have been
204 implemented in developed countries, for example the Carolina Express Licensing Agreement,
205 University of Missouri and University of Texas, University of California San Diego cases, the
206 Stanford University Network, and others (Mustar et al., 2006; Chapple et al., 2005; Grimaldi et al.
207 2011). However, universities in many developing and transition countries do not have the same
208 organizational flexibility or high-quality academic entrepreneurship ecosystems.

209 While the TTO was not an invention of national regulation in transition economies, as with
210 their counterparts in developed countries, the TTOs activities include, but not limited to collecting
211 information on their external partners, registering contracts and protecting the IP (Lockett et al.,
212 2003; Markman et al., 2005b; Lockett and Wright, 2005; Siegel et al., 2007; Perkmann et al., 2013;
213 Huyghe et al., 2016). To illustrate wider TTO's functions in transition economies, we use an
214 example of TTO in a leading regional university in Belarus which includes collection, analysis,
215 creation of a data banks, dissemination and collection of information on research activities of the
216 university and enterprise needs; participation in conferences, seminars, exhibitions; registration and
217 signing contacts between university and researchers as well as industry; implementation of
218 scientific research, exchange of scientific and technical information with national and foreign
219 institutions, provision of information to other technology transfer centres; facilitation of scientific
220 research and development; training scholars and researchers (GSTU, 2017). Two important TTo
221 functions are missing. First, evaluating the invention and deciding whether or not to pursue
222 acquiring a patent (copyright, trademark). This is usually done in negotiation with scientists and
223 potential user of the invention. Second, investing in invention as well as involvement of scientists
224 in the further stages of extensive adaptation of invention (Bradley et al. 2013).

225 Finally, at the individual level of analysis, we observe the individual characteristics of
226 scientists and incentives that lead scientists to become involved in the commercialization of

227 invention (van Looy et al. 2004; Jain et al. 2009; Guerrero and Urbano, 2014) and facilitating
228 knowledge spillovers (Audretsch, 2014). Scientist's decision-making and a choice of the knowledge
229 transfer model is affected by the ecosystem and university levels, and in particular by their
230 perception of the efficiency of the organizational mechanisms (TTOs, incubators, techno parks and
231 so on) (Kenney and Patton, 2009; Kolympiris and Klein, 2017). The theoretical framework has its
232 roots in the field of Entrepreneurial Theories (ET), investigating the individual attributes and
233 incentives (Kenney and Patton, 2005; Jain, et al. 2009; Parkmann et al. 2013; Guerrero and Urbano,
234 2014) which affect how research is commercialized (Thursby and Thursby, 2004).

235

236 **2.3. Conceptual model and research hypotheses.**

237 The process of research commercialization is multi-dimensional (Figure 1). Firstly, individual
238 characteristics matter (e.g. position, field of science (basic, applied), proportion of time dedicated to
239 research versus teaching, administration or commercialization, age of scientists, number of research
240 publications) (Aldridge and Audretsch, 2011). Secondly, university environment, institutions (e.g.
241 TTO, Centers for commercialization) and university ownership matter (Algieri et al. 2013). Thirdly,
242 the ecosystem stakeholders influence the entrepreneurial efforts and decision-making on research
243 commercialization (Kenney and Patton 2009).

244 A traditional university knowledge transfer model (Siegel et al. 2003) includes the active role
245 of organizational mechanisms in facilitating research commercialization (Bradley et al. 2013). The
246 academic entrepreneurship concludes that organizational mechanisms are not homogeneous across
247 universities (Mowery et al. 2004). Availability of financial resources and practice-oriented staff, a
248 strong business reputation and a number of successfully-completed contracts since the TTO was
249 established (Markman et al., 2005a), are important if TTOs are to market invention and to generate
250 new university start-ups and spin-offs (Meyer 2003; Siegel et al., 2003).

251 The prior literature also questions the efficiency of TTOs as facilitators of research
252 commercialization (Siegel et al., 2007; Wright et al., 2007; Kenney and Patton, 2009; Markman et
253 al., 2005b; Aldridge and Audretsch, 2011; Perkmann et al., 2013).

254 Aldridge and Audretsch (2011), who studied a sample of highly productive scientists in the
255 US found that 30% would choose a ‘backdoor route’ to commercialization. Although the process of
256 direct market commercialization by researchers is complex and requires substantial financial
257 resources, if the TTO is perceived as a barrier then the scientist will attempt to bypass it (Link et al.
258 2007). Broadman and Ponomariov (2009) applied the university perspective using the national
259 survey of tenured and tenure-track scientists in the US “research intensive” sectors explain, why
260 university scientists choose direct interactions with private companies in commercialization of
261 technology, instead of going a traditional TTO route (Siegel et al. 2004).

262 In the context of post-socialist economies (Marozau and Guerrero, 2016), TTO face high level
263 of university bureaucracy, absence of economic motivation for TTO staff to commercialize
264 inventions, lack of financial resources to independently market technology, lack of freedom in
265 decision-making to acquire a patent, lack of industry engagement and networking (Kerr and Nanda,
266 2009; Yegorov, 2009). Altogether these factors create significant organizational filters to
267 knowledge transfer and spillover via TTOs (Siegel et al. 2003; Mowery et al., 2004; Powers and
268 McDougall, 2005; Mustar et al., 2006; Huyghe et al., 2016).

269 Firstly, and the least of scientist’s concern, disclosure of invention puts the novelty of the
270 invention at risk of reengineering and copying by competitors, if TTOs staff starts marketing the
271 invention before the IP protection is sought (Lockett and Wright, 2005; Berman, 2008). The pay-
272 scale in the public sector in transition economies limits the hiring of competent TTO staff and
273 economic motivation (Wright et al., 2008), which increases the risks of non-commercialization or
274 unintended knowledge outflows.

275 Secondly, high level of bureaucracy and weak IP rights regulation may postpone application
276 for a patent and partner search (Siegel et al., 2003), increasing the time from the discovery to
277 adoption by industry.

278 Thirdly, complex and restrictive IP rights clauses included by university TTOs lawyers
279 discourage ecosystem stakeholders to collaborate (Freitas et al., 2013). When marketing technology
280 to industry, the TTO should be efficient in navigating conflicts of interests and values between a
281 scientist, university and a private firm (Slaughter and Rhoades, 2004), which rarely happens.
282 Monetary benefits are of great concern to both TTO and a firm, with TTOs having obtained IP
283 rights on patented technology may be hard to negotiate. A widely-used public university practice in
284 transition economies is to take away the IP right from the inventor (Marozau and Guerrero, 2016).

285 Fourthly, technology adoption typically requires ongoing collaboration with the inventor in
286 order to commercialize technology, which may become difficult as inventor does not hold property
287 rights and may refuse to collaborate. Unlike in the US, when university scientists receive federal
288 grants (Bercovitz et al. 2001), in the transition economies, university receives government grants to
289 serve large publicly-owned enterprises with new technology, where the economic interests of
290 scientists are not considered (Marozau and Guerrero, 2016) and the invention is fully-owned by a
291 university or a national government.

292 Fifthly, major part of university inventions are nascent in nature and “years away from
293 commercialization” (Bradley et al. 2013: 586). The original invention may be significantly changed
294 at adaptation and utilization stages with or without inventor’s involvement in a process, increasing
295 the uncertainty and risk for a TTO.

296 One of the interesting facts acknowledged in the recent TTO literature (Grimaldi et al. 2011;
297 Siegel and Wessner, 2012; Kolympiris and Klein, 2017) is that universities may have few research
298 results worth commercializing, in particular due to embryonic nature of technology which may
299 require significant further modifications (Bradley et al. 2013).

300 Finally, for universities in transition economies, TTO is a new phenomenon, because there

301 was little need for mechanisms of knowledge commercialization and IP right protection in a highly
302 centralized planning system with stable production chains (Yegorov, 2009). The regulation aiming
303 to encourage university knowledge transfer has now just begun to develop.

304 For example, Presidential Decree #59 on the Commercialization of the Results of Scientific
305 and Technological Activities Created at the Expense of Public Funds (Etalonline 2013), known as
306 the ‘Belarusian Bayh-Dole act’, tends to confer the IP rights arising from state-funded R&D to
307 universities that receive funding. This legislative initiative is of great importance, since research
308 institutes and university R&D expenditures are funded primarily from the state budget (66%).
309 Meanwhile funding from universities is negligible, accounting for less than 1% (Scienceportal,
310 2014).

311 Although TTOs could have created synergistic networks among scientists, industry, university
312 and governments (Bercovitz et al. 2001; Miller et al. 2014), connecting inventors to ecosystem
313 stakeholders that want to adopt university technologies, in transition economies, the implementation
314 of Etzkowitz’s (2003) model of knowledge transfer remains limited. A TTO is often perceived by
315 scientists as an additional bureaucratic structure “registering overhead costs” which is “just there” at
316 university (Yegorov, 2009; Marozau and Guerrero, 2016). Scientists in transition economies are
317 likely to choose alternative models of research commercialization (formal and informal) (Boardman
318 and Ponomariov, 2009). We hypothesize:

319 *H1: In transition economies there is a neutral impact of TTOs on university research*
320 *commercialization.*

321

322 The traditional model of university knowledge transfer (Siegel et al. 2003, 2004) does not
323 accurately capture the complexities of the process. For example, the marketing of invention does
324 not usually start before the TTO pursues a patent, TTO gauges the industry interest before investing
325 resources into IP protection and further research (Bradley et al. 2013). In troubled transition
326 economies with weak institutions and dominance of public sector in science, Etzkowitz’s (2003)

327 and Kenney and Patton's (2009) research commercialization models may not exactly work. First,
328 the ownership is never vested with an inventor to freely choose the commercialization route.
329 Second, inventor as a university employee may not receive a market price when contracting with
330 TTO. Third, loopholes in labor market regulation allow scientists to be full- or part-time employed
331 by a private firm (profit or non-for-profit) as well as perform entrepreneurial activities jointly with
332 industry (e.g. guest talks, paid consulting, technology transfer, copyrights, mentoring, supervising,
333 testing products). In these circumstances an alternative university knowledge transfer model is
334 applied.

335 To formulate an alternative knowledge transfer model, Heinzl et al (2013) look into factors
336 that can influence university technology transfer performance, such as research funding,
337 organizational environment, ecosystem stakeholders and the mechanisms of technology transfer.
338 Financial resources to commercialize an invention is one of the biggest issues confronting scientists
339 (Kerr and Nanda 2009). It is widely acknowledged (Clarysse and Moray, 2004, 2006; Bekkers and
340 Freitas, 2008; Clarysse et al. 2011; Miller et al. 2014) that the direct industrial funding may provide
341 needed resources (Etzkowitz, 2003). The process starts from commercial and societal needs when
342 firms seek academic resources before contacting a university or scientist to commercialize the
343 technology (Van Rijnsoever et al. 2008).

344 Except of private industry, who has already identified and use the technology (Aldridge and
345 Audretsch, 2011), other ecosystem stakeholders (e.g. banks and venture capitalists) are unlikely to
346 directly finance university research. This is due to the high risk and asymmetric information on the
347 market value of invention (Kerr and Nanda, 2009; Perkmann et al. 2011) and inability to market
348 invention (Sedaitis, 2000; Leydesdorff et al., 2015).

349 Empirical precedents for assessing the impact of direct industrial funding of university
350 technology have found that having industry grants increases the involvement of university scientists
351 in rapid technology development and collaboration with scientists working in private companies
352 (Bozeman and Gaughan, 2007), having industry grants increases the likelihood of interacting with

353 private firms in any capacity, including informal knowledge exchanges as well as performance of
354 entrepreneurial activities (Boardman and Ponomariov, 2009), having industry grants increases the
355 favourable attitudes towards university-industry collaboration (Bogler 1994) as well as academic
356 entrepreneurship activity and publication rates (Van Looy et al. 2004). The links and the degree of
357 industry involvement is the result of individual and mutual choices in a two-sided market of
358 scientists and private firms (Banal-Estanol et al, 2015).

359 Private companies identify technologies that they want and directly fund research projects at
360 universities (Van Looy et al. 2004; Perkmann et al. 2011b, 2013). Since industry pays for the
361 research it has an interest in adopting the major research technologies (Wright et al., 2006). Also,
362 firms aim at rapid commercialization and marketing an invention, because the benefits of
363 innovation may depend on how quickly the product is adopted (Siegel et al. 2003, 2004).

364 In transition countries, direct industrial funding takes place through various channels:
365 outsourcing part of industry research to university scientists (full- or part-time employment);
366 scientist's employment at satellite firms of multinational companies (Zalewska-Kurek et al., 2016)
367 or at headquarters and branches abroad; collaboration with industry scientists via guest talks, paid
368 consulting, technology transfer, including transfer of special competences, access to special data,
369 equipment and infrastructure, funds (Boardman and Ponomariov, 2009).

370 Direct industrial funding of university research is preferred for scientist in a transition
371 economy for the following reasons. First is commercialization income. Public grants are normally
372 given to low-risk applied research under strict requirements and with public or university ownership
373 of the research outcomes, while direct industrial funding provides additional commercialization
374 income, access to industry financial and technical resources, infrastructure, scientists and data
375 (Melin, 2000; Díez-Vial and Montoro-Sánchez, 2016). Second is control. University ownership
376 systems limits start-ups and spin-offs, as technology is publicly owned and its commercialization is
377 limited (Damsgaard and Thursby, 2013). For example, if the research project is unsuccessful (if a
378 new product does not start selling within three years of its invention), the research investment

379 should be returned to the public sponsor (Etalonline 2013). Unlike public funding, direct industrial
380 funding has “negotiable” ownership systems on invention (e.g. scientists co-owns new technology).
381 Third is flexibility. Direct industrial funding makes it easier to modify the research results if
382 additional tasks or further adaptation is required (Bradley et al. 2013). This is unlikely with the
383 public grants with limited budgets, strict deadlines on invention and dissemination periods. Fourth
384 is networks. Direct industrial funding opens new possibilities for informal interactions, such as
385 further consulting and collaborative research while further development of technology (Broadman
386 and Ponomariov, 2009). Finally, it is co-ownership on invention. Commercialization agreement is
387 signed between a private company and an inventor (inventor-ownership system) (Perkmann and
388 Walsh, 2010; Hvide and Jones, 2016) and not between a private company and a TTO (university-
389 ownership system), when inventor may not be able to claim IP rights.. In the best possible contract
390 with industry, an inventor will receive a share in royalty on gross revenues or profits.

391 Political actions aimed at encouraging knowledge transfers using direct industrial funding
392 have recently begun to develop further in transition economies (Bajmócy et al. 2010; Etalonline,
393 2013). We hypothesize:

394 *H2: In transition economies direct industrial funding facilitates knowledge transfer from*
395 *university.*

396

397 **2.4. Context of transition countries**

398 We test our hypotheses using individual scientist data from three economies: Belarus,
399 Kazakhstan and Azerbaijan. They are rather peculiar, but representative transition economies.
400 Belarus has a small, open economy and is one of the very few ‘soviet’-type countries left, which has
401 recently embarked on significant market reforms and support to information technology sector.
402 Meanwhile, Kazakhstan and Azerbaijan are transition economies largely based on natural resources
403 such as oil and gas. The economic and technological dynamics of these three economies depend to a
404 significant extent on the absorption of new foreign technologies and knowledge (Marozau and

405 Guerrero, 2016). Multinational enterprises have started to be major actors in business R&D with
406 developing linkages to university research.

407 Since 1991, Belarus, Kazakhstan and Azerbaijan have made greater efforts towards economic
408 openness, trade and investment in new universities, adoption of effective mechanisms for research
409 commercialization and market-based relations between research institutes, universities and
410 enterprises (Yegorov, 2009). They have inherited a relatively well-developed science and
411 technology system of the Soviet Union, however there is still a weak system of economic incentives
412 and research commercialization (Radosevic, 1998).

413 The economy of these countries is still significantly dominated by large public sector
414 enterprises in machinery, agriculture, oil and gas. Although Belarus has remained much more
415 ‘Soviet’ than modern Russia, Kazakhstan or Azerbaijan, they are similar with regards to their
416 academic cultures, methods of public support and control over their education and research sectors,
417 government regulatory tools and control over industry and IP rights. Fewer universities compete
418 internationally for publications and international students, with research budgets predominately
419 spent on wages (Yegorov, 2009). Interestingly, unlike universities in Kazakhstan and Azerbaijan,
420 Belarusian universities that were established in the Soviet era have been preserved.

421 Analysis of knowledge commercialization in these countries as post-Soviet transition
422 economies has important implications, and is relevant to other transition economies in the former
423 Soviet countries (Varblane et al. 2007b).

424 Overall, the higher education sector is unattractive for young people due to low wages, lack of
425 academic freedom and public (university) ownership on invention. Scientists struggle to
426 commercialize their inventions via a traditional model of university knowledge transfer, aiming to
427 get a part-time employment at multinational firm research labs and collaborate with their scientists.
428 As in other transition countries such as Estonia (Mets, 2009), universities in Belarus, Azerbaijan
429 and Kazakhstan have problems attracting internationally recognized scholars.

430 There are major differences between research commercialization in Belarus, Azerbaijan and
431 Kazakhstan and in catching-up economies such as Estonia, Hungary, Latvia and Lithuania. The
432 main difference is their ability to learn “how to...” and efficiently transfer technology to industry.
433 Research commercialization models applied in Estonia, Latvia and Lithuania have been tested in the
434 “West” and have become a new emerging institutions (Varblane et al., 2007b). In Estonia, for
435 example, research culture includes establishing and publishing in internationally peer-reviewed
436 journals, grant applications, , performance-based distribution of public research funding (Mets,
437 2009), which does not happen in Belarus, Kazakhstan or Azerbaijan. IP protection and national
438 innovation systems provide more incentives to knowledge transfer, for example in Estonia
439 (Varblane et al. 2007b). Unlike in transition economies, many Estonian universities accepted “the
440 entrepreneurial paradigm of the university in the triple helix of University- Industry-Government
441 relations (Mets, 2006). This demonstrates that universities have begun to encourage the
442 development of spin-off companies (Bray and Lee (2000) and to licence technologies to an
443 entrepreneur (e.g. inventor or external partner) (Phan and Siegel, 2006).

444 This is unlikely to happen at universities in Belarus, Kazakhstan and Azerbaijan, as TTOs do
445 not establish spin-offs and start-ups, rather they perform an information brokerage function between
446 a university and investors (Lerner, 2005). Collaboration with industry remains the preferred
447 channel of knowledge transfer. Collaboration with other ecosystem stakeholders is limited. First,
448 the government already funds research via national grants with public ownership on invention (not
449 attractive to scientists). Second. angel and venture capital investment is limited in transition
450 economies due to gaps in investor protection. In addition, most of university technologies are at
451 early stage, increasing the risk and uncertainty on investment. Third, collaboration with non-for-
452 profit is negligible and is biased towards foreign grants and academic engagement such as
453 volunteering work without technology transfer. Finally, scientists have little access to foreign
454 universities and institutions outside their countries, including language barrier and lack of networks
455 (Kenney and Patton, 2005). These are the reasons, why research commercialization by scientists in

456 transition economies lags behind their Western counterparts, and that alternative knowledge
457 commercialization models are in place (Kerr and Nanda, 2009; Boardman and Ponomariov, 2009;
458 Kwiek, 2012).

459 Since existing innovation systems are still unable to link the knowledge creation to
460 knowledge commercialization (Varblane et al., 2007a, 2007b), the authorities made universities
461 rather than scientists responsible for university knowledge transfer. Many universities responded on
462 the call by establishing TTOs. This process was not fully thought through using the role models (Di
463 Gregorio and Shane, 2003; Mustar et al., 2006; Chapple et al., 2005; Powers and McDougall, 2005;
464 Grimaldi et al. 2011; Mosey et al., 2017), when knowledge transfer mechanisms are linked to
465 scientist incentives (Kenney and Patton, 2009; Perkmann et al. 2011b, 2013) facilitating the
466 individual mechanism of the knowledge spillover of entrepreneurship. Traditional universities in
467 Belarus, Kazakhstan and Azerbaijan were reluctant to change their practices, and responded with
468 the development of personal networks with practitioners and research authorities, building large
469 public consortia for collaboration contracts. The model of multilevel interactions between
470 ecosystem stakeholders, university and scientists (Figure 1) was largely ignored (Degroof and
471 Roberts, 2004; Audretsch, 2014). Consequently, the majority of scientists have been unaware of
472 how to commercialize their research via TTO, and what are the implications of research
473 commercialization: where to find customers and what exactly can and cannot be commercialized?
474 Several legal prosecutions of scientists who informally collaborated with industry have been
475 broadcast in the media in the 2000s, which was not conducive to academic entrepreneurship in a
476 region (Yegorov, 2009). The main obstacles remain an underdeveloped entrepreneurship ecosystem
477 (Grimaldi et al. 2011; Leydesdorff et al. 2015; Theodoraki and Messeghem, 2017), a lack of
478 economic incentives (Guerrero et al. 2014, 2016), and financial resources (Tchalakov et al., 2010).

479

480 **3. Methodology**

481 **3.1. Data, sample selection issues and estimation strategy.**

482 The empirical analysis is based on a novel cross-sectional dataset constructed via online
483 survey over three years from November 2015 to August 2017 as the Academic entrepreneurship
484 survey for Belarus, Kazakhstan and Azerbaijan. Participation in the survey was optional. The data
485 collected in this study is the first attempt for generating statistics on university knowledge transfer
486 in transition economies which are not collected by official statistics or by university scientists or
487 TTOs. The online survey generated a comparatively small dataset that could be plagued by a non-
488 response bias or information disclosure bias.

489 The data has been thoroughly reviewed by the authors. Unique features of the survey include
490 sampling for representativeness at the level of regions in each country (at least one university in
491 each country region and two leading universities in capital-city), university ownership (a balanced
492 number of private/public universities), university size (medium and large) and field of study (at
493 least 4 different faculties within each university) and scientist academic position (junior and senior
494 scientists). The scientific disciplines include mathematics, physics, medicine, chemistry,
495 engineering, agriculture, geosciences, economics and management, sports. The data was collected at
496 20 universities in three transition countries: Belarus (8 out of 35 universities with approx. 40% of
497 professors' coverage), Kazakhstan (8 out of 61 universities with approx. 30% of professors'
498 coverage) and Azerbaijan (4 out of 28 universities with approx. 44% of professors' coverage).¹
499 Table A1 in Appendix A provides a list of universities participated in the survey. These countries
500 were selected building upon the societal clusters proposed by the Global Leadership and
501 Organizational Behavior Effectiveness research program (GLOBE) that groups countries on the
502 basis of cultural dimensions and similar institutions (Huyghe et al. 2016).

¹ We do not have full data on a sample distribution by university as it was not a mandatory question in the survey. The data does not allow us to identify individuals as neither university name, department name nor university email were mandatory answers. Moreover most researchers and faculty members in the countries in focus have Google or email boxes external to the university. We see it as a way to enable greater confidentiality and avoid disclosure. In order to maintain confidentiality, we left university name and email optional in addition to giving a no-disclosure promise. Very few researchers provided university names, but were more collaborative on Google and email accounts. We thank one anonymous reviewer for drawing our attention to explaining this.

503 We started by collecting email and telephone information for the 4,705 established scientists
504 via the universities' web-pages by script with the help of the Python programme. The records
505 could generally be found by typing their full name, university and department. The ensuing e-mail
506 accounts were then collected and registered in the scientist database. Of the 4,705 scientists
507 identified and emailed, 2,602 responded. This means the initial response rate was 55.30 percent.
508 Only a subsample of individual observations were defined as academically active, and provided
509 information on commercialization income as a share of total income as well as other
510 commercialization activity characteristics. As this might cause a selection bias, regressions based on
511 such survey responses are commonly estimated using a two-stage approach (Heckman, 1979). In
512 this, the subsequent second stage includes a control for unobserved determinants of selection
513 estimated in the first stage (Crépon et al., 1998). Consequently, when an individual does not
514 disclose income from commercialization it may mean they have an income, but do not wish to
515 disclose it, or that they do not know their own income. It would be incorrect to exclude these
516 observations, because the estimation of specific individuals may be biased by the fact that the
517 individual is not properly identified by commercialization income. In the approach used here
518 (Figure 2) both biases have to be accounted for. To address the disclosure bias we conducted a
519 probit regression on all 2,602 individuals identified:

520

$$521 \quad \textit{Selection step one} : Pr(\textit{Disclosure} = 1 \mid x_i^1) = \Phi(x_i^1 \beta) \quad (1)$$

522 where x_i^1 contains the variables capturing scientist age, position (associate professor, full
523 professor, researcher) and the type of commercialization activity a scientist is involved in (e.g.
524 honorarium, establishing a spin-off, licencing patents, product sales without spinoffs, public grants
525 and spin-off establishment). We also include country and year fixed effects. Based on this
526 regression, the Inverse Mill's ratio was calculated. It is included in the final outcome regression to
527 control for the disclosure of commercialization information selection bias, also known as
528 independence bias (Herstad and Ebersberger, 2015).

529 By restricting this analysis to the 424 observations where the individuals all report
530 commercialization income (positive or zero), it is possible to use the additional information
531 available from the survey to estimate the likelihood of an individual to be active or not active in
532 research commercialization. There is a group of scientists which are involved in at least one type of
533 commercialization activity, but report no commercialization. For those observations we define a
534 “commercialization active” bias. We conducted a probit regression on 424 individuals identified:

535

$$536 \quad \textit{Selection step two: } Pr(\textit{Active} = 1 \mid x_i^2) = \Phi(x_i^2 \beta) \quad (2)$$

537 where x_i^2 includes characteristics assumed to affect the decision to carry out
538 commercialization activities, including country and year fixed effects. This includes researcher’s
539 age, university ownership and the source of research financing (private, government, foreign,
540 university or self-sponsorship) as well as type of external sponsor of research.

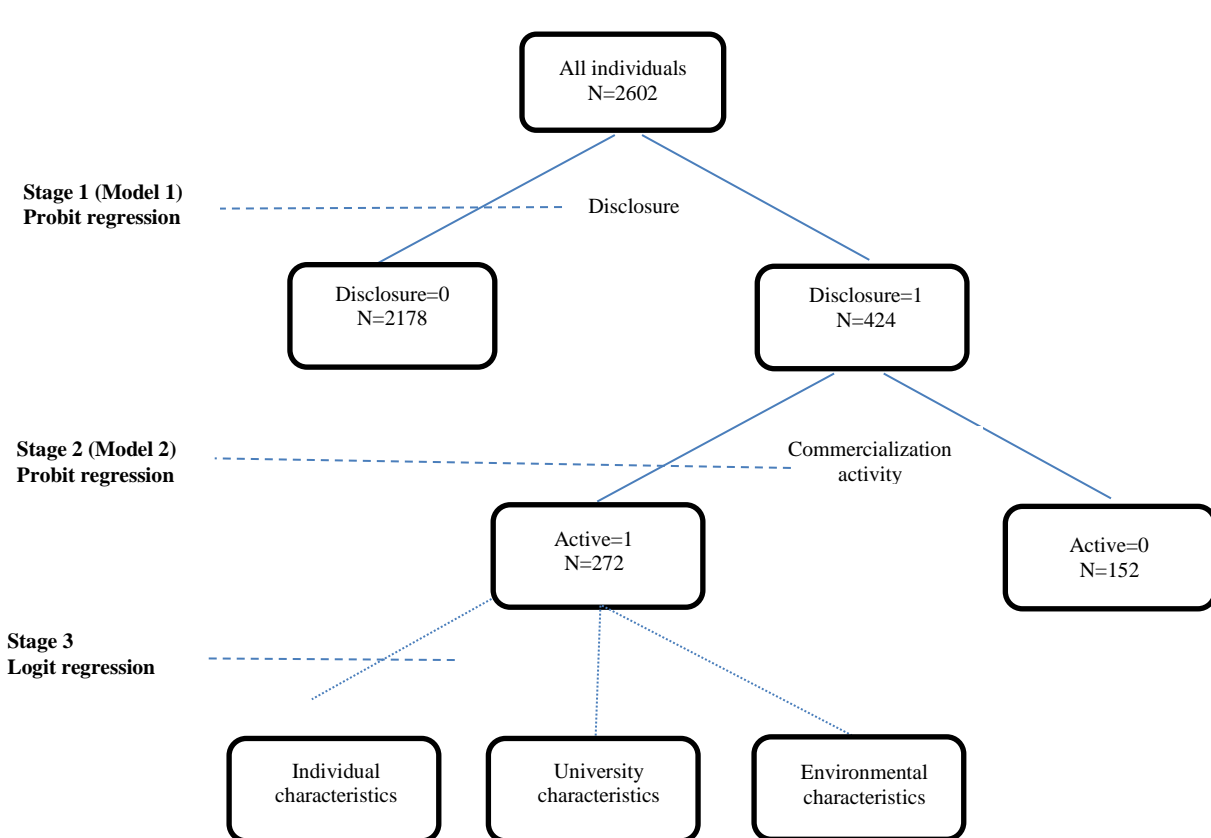
541 Furthermore, financing research should positively influence the propensity to engage in
542 current commercialization activity (Kerr and Nanda, 2009). University ownership (private vs.
543 public) may also influence the decision to engage in research commercialization as well as
544 scientist’s age (Crépon et al. 1998). Based on this selection regression a second Inverse Mill’s ratio
545 was calculated which was included in the final outcome regression. The correction of two selection
546 biases by means of the three-step model employed here requires two instruments to produce
547 credible estimates. In each stage, at least one variable has to determine selection without affecting
548 the final or subsequent stages (Heckman, 1979; Green, 2000). The results of the selection equations
549 are reported in Table A2 in Appendix A.

550 In Model 1 (Table A2), scientist age is measured as a natural logarithm as well as licencing
551 patents. Professors and individuals involved in multiple forms of commercialization activity were
552 found to be more likely to disclose their commercialization income.

553 It is notable no significant impact was detected from other types of commercialization
554 activities on disclosure bias. In Model 2 (Table A2), individuals whose research was financed by

555 foreign and government grants are more likely to be commercially active, while individuals who
 556 self-sponsored their research were less likely to be actively commercialising their research.

557 In order to control for potential bias related to presence (or not) of TTO at university (not all
 558 universities had TTOs, see Table A1), we follow Green (2002) procedure to control for it. We
 559 include binary variable “TTO at university” which controls whether or not a TTO is established and
 560 continuous variable “TTO contracts” which illustrates a number of contracts signed via TTO in our
 561 empirical model. Once above variables are included the model will capture decision making on
 562 research commercialization by scientists located at universities with and without TTO. Our final
 563 sample of 272 researchers consisted of 38 researchers from Azerbaijan, 94 from Belarus and 140
 564 from Kazakhstan.



591 Figure 2: Estimation strategy

592 In most instances, we set up response deadlines and asked university administrators (Deans,
 593 Head of Schools, departments and where applicable deputy vice-chancellors) for assistance to
 594 disseminate survey questionnaires to increase the response rate. The survey targeted both non-
 595 tenured and tenured academic staff (Muscio, 2010; Cunningham and Link, 2015).

596 To support our quantitative approach we used a mixed-methods analysis which involved
597 randomly selecting and face-to face interviewing scientists and TTO managers from the survey
598 sample. We performed 27 face to face interviews (9 in Belarus, 14 in Kazakhstan and 4 in
599 Azerbaijan) with university scientists and TTO managers during April 2016 - September 2017.
600 Interviews were optional and strictly confidential. Appendix B1 describes the interview sample and
601 Appendix B2 introduces the interview protocol and eligibility criteria for respondents.

602 The average age of the respondents was 47.5 years, average experience of research and
603 teaching 22 years, and average commercialization rate being 23 percent in the income. With regards
604 to administrative position and university ownership, 66 percent of respondents were members of the
605 faculty board, 55 percent worked in public universities and 45 percent worked in private
606 universities. Interestingly, only 44 percent of respondents used TTO services or had signed a
607 contract with TTO.

608 A list of interviewees was created from the individuals who participated in a survey with and
609 left their email willing to stay in touch. These were researchers, managers of business incubators,
610 university technology transfer officers and professors. In addition, a snowball technique was used
611 during the interviews. In this case, the respondents were asked to mention other researchers they
612 knew to provide further opportunities to obtain data. We delineated the population of respondents
613 from these universities based on the following criteria. Firstly, the respondent needed to satisfy the
614 condition of commercialising knowledge and technology created at the university. Secondly, the
615 respondent had to be actively involved in various commercialization activities, with a share of
616 commercialization in total income being positive. Further, the respondent needed to collaborate
617 with at least one ecosystem stakeholder on research commercialization (e.g. university, government,
618 private industry rather than self-sponsoring his(her) research).

619 We identified scientists in both junior senior positions who were competent to comment,
620 advise and suggest changes in research commercialization policy in these countries. They also
621 advised us on mechanisms and loopholes in the IP rights and academic entrepreneurship ecosystem,

622 where scientists face significant challenges related to co-ownership of invention, engagement with
623 TTOs, private industry, government and adoption of research outcomes. Interviewees has advised
624 which areas needed to be targeted by foreign investors interested in commercializing research
625 outcomes in Belarus, Kazakhstan, Azerbaijan and economies-like.

626

627 **3.2 Variables**

628 To be included in a sample, all questions related to the variables of interest need to be
629 completed with no missing values. All missing values and non-applicable answers were labelled as
630 missing and therefore excluded from our sample. We proxy research commercialization activity
631 with a share of scientist's annual income from commercialization activities in total income, which is
632 our dependent variable (Wright et al. 2007, 2009; Grimaldi et al. 2011; Siegel and Wright, 2015).
633 The resulting dependent variable was further scaled on the interval [0,1] with the average of 0.14
634 (14% of annual income from commercialization activity), the lowest share equal zero and the
635 highest share of commercialization equals 0.90 which is 90% of annual income coming from
636 research commercialization. We applied a multi-level approach (Grimaldi et al., 2011; Guerrero and
637 Urbano, 2013; Miller et al. 2014; Theodoraki and Messeghem, 2017) to the process of research
638 commercialization with variables at ecosystem level, university (organizational level), and scientist
639 (individual level).

640 Our individual level control variables (CVs) build on Wright et al. (2007), Boardman and
641 Ponomariov (2009), Aldridge and Audretsch (2011), Grimaldi et al., (2011), Guerrero and Urbano
642 (2013) and Banal-Estañol et al. (2015) include: researcher's professional and personal
643 characteristics, such as number of works published in the last 5 years; academic position at the
644 university; share of research in total workload; self-sponsorship of research (if any). Individual level
645 has one explanatory variable (EV) which is individual's TTO awareness at university. TTO
646 awareness may reflect the scientist's level of engagement in commercialization. A positive
647 relationship suggests that TTO awareness would increase research commercialization.

648 Our organizational level CV is university ownership (Aldridge and Audretsch, 2011; Clarysse
649 et al. 2011), which takes a value of one for scientists employed at public universities and zero
650 otherwise. Because they are at least partially financed by the government, public universities are
651 limited in appropriation of IP rights on university research results. For example in Belarus, this has
652 only become possible with adoption of the ‘Belarusian Bayh-Dole act’ (Etalonline 2013).

653 Organizational level has two EVs. First is binary variable equals one if TTO is established at
654 university. Second is the number of contracts signed between a TTO and a scientist, which is a
655 university-level variable. Drawing on Wright et al. (2007, 2008, 2009), Banal-Estanol et al. (2015)
656 and MIT REAP framework (2017) ecosystem level CVs includes direct funding of research by
657 ecosystem stakeholders such as government, industry, risk capital, foreign firms, non-for-profit
658 (NGO) (Siegel et al. 2004; Bradley et al. 2013).

659 We followed Thursby and Thursby (2004), Grimaldi et al. (2011); Miller et al. (2014), as
660 well as Theodoraki and Messeghem (2017) by asking researchers if they collaborated in their
661 research with any of ecosystem stakeholders (such as industry and professional associations, foreign
662 industry or academia, public institutions or government, non-for-profit or universities).² Ecosystem
663 level has one binary EV - direct industrial funding. Our model includes country and year fixed
664 effects. Table 2 illustrates the list of variables at the individual, university and ecosystem levels.
665 These are to be used as explanatory and control variables to test our research hypotheses. Table 3
666 illustrates a correlation matrix of variables used in our final sample.

667

668

669

² As part of the ecosystem we also controlled for the following variables at country level: GDP per capita and population size (millions) from the World Bank development indicators; Global innovation index from the Global innovation index report; patent applications by residents and non-residents per 100,000 residents from the World Bank data and Corruption Perception Index from Transparency International. We used two-year lagged values for these variables to address the issue of endogeneity. Inclusion of these country controls has not changed the coefficient signs, confidence intervals or significance level in our the estimation model (3) . Neither has it improved the model specification and goodness of fit, as all macroeconomic indicators were not statistically significant. This means that changes in the entrepreneurship ecosystem related to socioeconomic conditions, innovation and informal institutions do not change the degree of research commercialization by scientist. Our country dummies, which control for country fixed effects, were not statistically significant. We thus decided to keep country controls using the fixed effect approach (Green, 2002). We thank one anonymous reviewer for drawing our attention to this.

670 Table 2: Description of dependent, independent and control variables.

Variables	Variable description	Mean	St. dev	Min	Max
<i>Individual characteristics</i>					
Commercialization share (DV)	Share of income, funds coming from commercializing research, % (on scale from zero to one)	0.14	0.18	0.00	0.90
Published works	Number of works published in the last 5 years	23.12	16.76	0.00	60.00
Researcher	Research fellow position equals one, zero otherwise	0.13	0.34	0.00	1.00
Ass. Professor	Associate Professor position equals one, zero otherwise	0.36	0.48	0.00	1.00
Research in workload	Share of research in total work 1-(0-25%) to 4 (75-100%)	1.73	0.81	1.00	4.00
Self-sponsor	Research is self-financed equals one, zero otherwise	0.29	0.45	0.00	1.00
TTO awareness	Researcher is aware of a TTO established at university equals one, zero otherwise	0.33	0.47	0.00	1.00
<i>University characteristics</i>					
TTO contracts	Number of contracts signed via TTO	0.46	1.41	0.00	8.00
TTO at university	TTO is established at university, zero otherwise	0.64	0.48	0.00	1.00
Private university	Private university equals one, zero otherwise	0.27	0.44	0.00	1.00
<i>Environmental characteristics</i>					
University sponsor	Research is financed by university equals one, zero otherwise	0.19	0.39	0.00	1.00
Industrial funding	Direct industrial funding of research and technologies) equals one, zero otherwise	0.10	0.29	0.00	1.00
Foreign	External stakeholder: foreign institutions (industry and academia) equals one, zero otherwise	0.25	0.43	0.00	1.00
Industry	External stakeholder: industry and professional associations equals one, zero otherwise	0.18	0.39	0.00	1.00
University	External stakeholder: other academic institutions equals one, zero otherwise	0.38	0.49	0.00	1.00
NGO	External stakeholder: NGOs equals one, zero otherwise	0.12	0.33	0.00	1.00
Public	External stakeholder: public institutions or government equals one, zero otherwise	0.22	0.41	0.00	1.00
Lambda 1	The inverted Mills ratio for disclosure bias	1.58	0.43	0.76	2.85
Lambda 2	The inverted Mills ratio for commercialization active bias	0.27	0.16	0.01	0.60

671 Note: Number of researchers in final sample: 272.

672 Source: Academic entrepreneurship survey data for Belarus, Kazakhstan and Azerbaijan (collected 2015, 2016 and 2017).

Table 3. Correlation matrix.

	1	2	3	4	5	6	7	8	9	10	11	12	13
1 Commercialization share	1												
2 Published works	-0.01	1											
3 Researcher	0.08	-0.18*	1										
4 Ass. Professor	-0.03	0.15*	-0.29*	1									
5 Research in workload	0.10	0.18*	0.16*	-0.06	1								
6 TTO contracts	0.05	-0.01	0.27*	0.02	0.11	1							
7 TTO awareness	0.01	0.08	0.11	0.02	0.10	0.40*	1						
8 TTO at university	0.07	0.03	0.16*	0.01	0.02	0.24*	0.53*	1					
9 Private university	-0.04	-0.02	-0.01	-0.04	-0.01	0.02	0.05	0.07	1				
10 University sponsor	-0.04	0.01	-0.07	-0.01	-0.05	-0.13*	0.01	0.02	0.01	1			
11 Industrial funding	0.26*	-0.03	0.09	0.01	-0.03	0.09	0.03	0.01	0.01	-0.11*	1		
12 Self-sponsor	-0.12*	-0.17*	-0.17*	0.13*	-0.10	-0.04	-0.14*	-0.12*	0.21*	-0.06	-0.07	1	
13 Lambda 1	0.12*	0.02	-0.06	0.13*	0.01	0.01	0.04	0.02	0.02	-0.11	0.17*	-0.01	1
14 Lambda 2	-0.13*	-0.19*	-0.07	0.05	-0.14*	-0.08	-0.13*	-0.08	-0.10	0.17*	-0.18*	0.56*	-0.12*

Note: Number of scientists: 272. * - 5% statistical significance level of the coefficient. Correlation coefficient are not presented for a set of dummies on collaboration with external stakeholders (industry, foreign institutions, public institutions, NGO and university) to save space.

Source: Academic entrepreneurship survey data for Belarus, Kazakhstan and Azerbaijan (collected 2015, 2016, 2017)

590 **3.3. Estimation method.**

591 We started our analysis by applying a multilevel generalized linear model to estimate a
592 fractional dependent variable. This was based on reports from individuals observed in the three
593 consecutive waves for Belarus and Kazakhstan, and one wave for Azerbaijan. The sample is
594 rotated, which means that individuals from one wave cannot be tracked in another, and the
595 estimations through a pooled estimation makes distinguishing between temporal or sampling effects
596 unfeasible. The selection of a multilevel estimation approach was based on the model introduced in
597 Figure 1 with the variables describing individual, university (organizational) and ecosystem
598 characteristics which affect the likelihood of research commercialization.

599 In a multilevel estimation, sometimes also called a hierarchical, random coefficient was not
600 statistically significant. The data structure in the population was thus not identified as hierarchical
601 (Goldstein, 2011). In other words, a multilevel generalized linear model was not feasible
602 (Goldstein, 2011). This means that neither variation in university characteristics (specification 2 and
603 3 and 5 and 6, Table A3) nor variation in country characteristics (specification 1 and 4, Table A3) in
604 each survey wave shaped research commercialization (Maas and Hox, 2005). Table A3 offers a
605 robustness check of the multilevel estimation with the distribution of dependent variables
606 (commercialization share) as binomial (specifications 1-3, Table A3) and Bernoulli (specifications
607 4-6, Table A3). Bearing in mind the issues pointed out by Baum (2008) when modelling
608 proportions as dependent variables, we estimated the generalised logistic model with three-level
609 controls and the fractional dependent variable y_{ijk} defined on the interval [0,1] such that:

610
$$g[E(y_{ijk})] = \beta_0 + \beta_1 x_{ijk} + \beta_2 z_{ijk} + \beta_3 \lambda_{ijk} + \varepsilon_{ijk} \quad (3)$$

611 where i is the individual at university j and country k . The explanatory variables are
612 presented by x_{ijk} , control variables are presented by z_{ijk} and the Inverse Mill's ratio for disclosure
613 and commercialization activity bias is λ_{ijk} as described in Crépon et al. (1998). We followed the
614 Heckman (1979) approach to compute two Inverse Mill's ratios (λ_{ijk}) from the equations (1) and

615 (2) and including them our final model (3) to control for selection bias. The presence and direction
 616 of a selection bias was inferred from the statistical significance and sign of the Mill's ratio
 617 coefficients in equation (3). Finally, ε_{ijk} is an error term. Equation (3) includes year and country
 618 fixed effects.

619

620 4. Results

621 4.1. TTO and university research commercialization

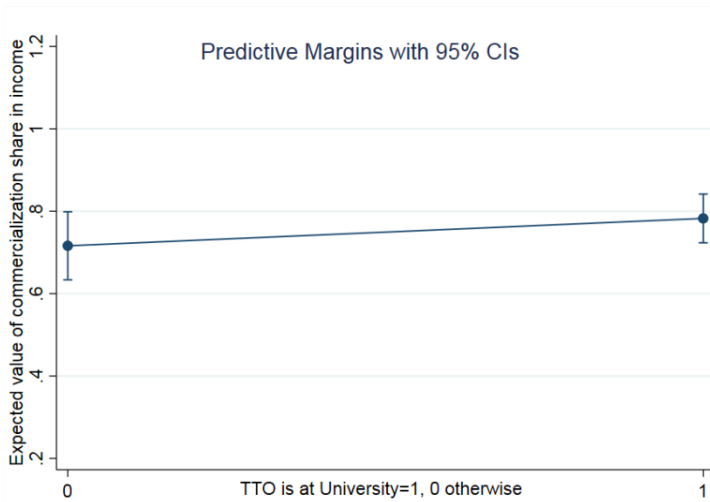
622 Table 4 provides the results of our model (3). Neither the establishment of the technology
 623 transfer office nor the number of contracts established via the TTO nor TTO awareness had a
 624 statistically significant impact on the commercialization share of scientist income, supporting H1
 625 (Table 4, spec. 1-3). The coefficient of TTO awareness ($\beta=0.605$; $p<0.12$) is positive, but
 626 statistically insignificant at a 10% level (Table 4, specification 3). Predictive Margins with 95%
 627 confidence intervals (CIs) in Fig.3 illustrate a similar level of commercialization share for scientists
 628 at universities with and without a TTO. Predictive Margins with 95% CIs in Fig.4 illustrate a
 629 similar level of commercialization share for scientists having different number of
 630 commercialization contracts with TTO. For example, scientists who have one or ten contracts with
 631 TTO are likely to have a similar level of commercialization income. Predictive Margins with 95%
 632 CIs in Fig.5 illustrate that who were aware or unaware of TTOs existence at university have a
 633 similar level of commercialization income.

634 Table 4: Generalised logistic model estimation with three-level controls

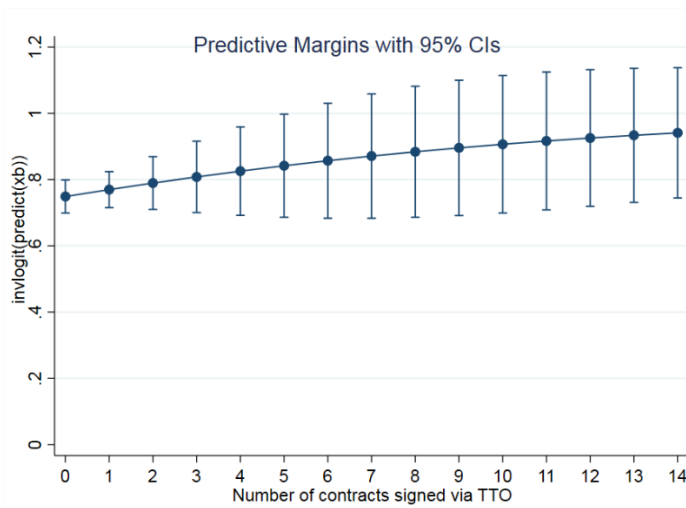
Model specification	(1)	(2)	(3)
<i>Individual characteristics</i>			
Published works	0.009 (0.01)	0.009 (0.01)	0.008 (0.01)
Researcher	0.312 (0.56)	0.281 (0.56)	0.356 (0.56)
Ass. Professor	0.626* (0.35)	0.609* (0.35)	0.625* (0.36)
Research in workload	-0.342* (0.19)	-0.358* (0.19)	-0.363* (0.20)
Self-sponsor	-0.599 (0.47)	-0.645 (0.46)	-0.601 (0.47)
TTO awareness (H1)			0.605 (0.36)

<i>University characteristics</i>			
TTO at University (H1)	0.413 (0.32)		
TTO contracts (H1)		0.152 (0.15)	
Private university	-0.213 (0.44)	-0.185 (0.44)	-0.178 (0.44)
<i>Environmental characteristics</i>			
University sponsor	-0.251 (0.39)	-0.191 (0.39)	-0.253 (0.39)
Industrial funding (H2)	1.778** (0.91)	1.782** (0.91)	1.764** (0.90)
Foreign	-0.07 (0.50)	-0.05 (0.51)	-0.06 (0.51)
Industry	-0.03 (0.54)	-0.01 (0.54)	-0.04 (0.55)
University	0.26 (0.47)	0.29 (0.47)	0.32 (0.48)
NGO	1.46** (0.71)	1.47** (0.71)	1.50** (0.72)
Public	0.52 (0.48)	0.48 (0.48)	0.51 (0.49)
The inverse Mills ratio for disclosure bias	-0.651* (0.37)	-0.658* (0.37)	-0.663* (0.37)
The inverse Mills ratio for commercialization active bias	-2.534* (1.49)	-2.614* (1.49)	-2.467* (1.49)
country = Belarus	0.910 (0.56)	0.986 (0.56)	0.953 (0.57)
country = Kazakhstan	0.095 (0.51)	0.180 (0.51)	0.088 (0.52)
Year 2016	0.862 (0.71)	0.941 (0.71)	0.933 (0.71)
Year 2017	1.185* (0.66)	1.305** (0.66)	1.253* (0.65)
Constant	1.703* (0.99)	1.796* (0.98)	1.758* (0.98)
Number of obs.	272	272	272
LR chi2	41.16	40.73	42.45
Log-likelihood	-130.13	-130.35	-129.49
Pseudo R2	0.13	0.13	0.14

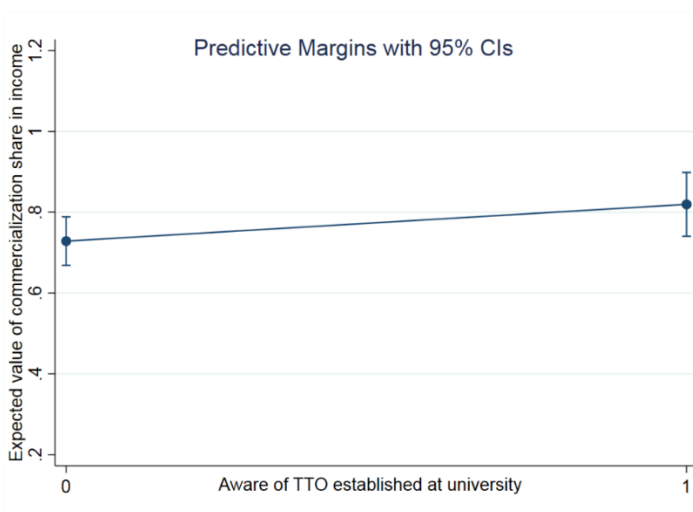
635 Note: Number of scientists: 272. Reference year=2015; Reference country=Azerbaijan. .***, ** and * Significance at
636 the 1%, 5% and 10% levels, respectively.
637 Source: Academic entrepreneurship survey data for Belarus, Kazakhstan and Azerbaijan (2015, 2016, 2017)



638
 639 Figure 3: Predictive Margins with 95% CIs: Expected commercialization rate and TTO
 640 establishment at university
 641



642
 643 Figure 4: Predictive Margins with 95% CIs: Expected commercialization rate and number of
 644 contracts established via TTO
 645



646
 647 Figure 5: Predictive Margins with 95% CIs: Expected commercialization rate and TTO awareness

648 The mixed method approach and 27 face-to-face interviews with TTO managers and scientists
649 were helpful in shedding more light on the role of TTOs in university knowledge transfer.
650 Interviewee four (I4) commented, “One of the reasons TTOs are not able to help scholars is the
651 institutional framework which is unfriendly in transition countries” confirming Yegorov (2009).
652 I(4) further laments: “TTOs in Belarus have highly bureaucratized rules and practices and lack
653 expert knowledge, and make it expensive to register contracts and run grants”, supporting Link’s et
654 al. (2007) findings. (I1) stated that, “TTOs are becoming university departments that process
655 documents for public funding and grants, and collect substantial shares of financing performing an
656 information broker to government, university and scientists, but not to investors (Lerner, 2005). (I5)
657 adds: “TTO for me equals bureaucracy” (Marozau and Guerrero, 2016). (I7) defended the
658 importance of TTOs at universities, but stated: “You need a person who collaborates with people in
659 the industry and with scientists. But such person is likely to be from a similar background that a
660 researcher to understand how a product works. An entrepreneur definitely needs to be an expert in
661 the product they manufacture. Companies that innovate need people even in marketing and other
662 areas who have PhDs in Physics, or in a very narrow specific field to understand it”(Lockett and
663 Wright, 2005; Berman, 2008). Hiring a competent TTO leader in transition economies is clearly an
664 issue (Wright et al., 2008).

665 In Azerbaijan the situation with TTOs is concerning. As (I27) commented, “Current state
666 legislation does not even allow universities or research institutions to use international grant funds.
667 In addition, one of the most challenging is the gap in the vision of top management with university
668 departments as well as departments such as TTOs”. This raises the importance of Kenney and
669 Patton’s (2009) and Grimaldi’s et al. (2011) argument regarding the creation of a regulation to
670 allow commercialization. Even though there are a number of highly-qualified researchers and
671 human resources at universities, the lack of understanding and vision of the top management
672 prevents successful research commercialization.

673 (I11) further adds to the efficiency of TTOs in transition economies: “Absolutely no

674 competence at TTO. They do not have experience of working in business or industry. No market
675 intuition, innovative ideas or knowledge of how to commercialize technology” (Link et al. 2007;
676 Wright et al., 2008; Kolympiris and Klein, 2017). Regarding the new generation of TTOs, (I21)
677 adds: “We are the Bekturov Institute of Chemical Sciences in Kazakhstan and commercialize
678 medical chemistry research, development of new to market drugs, with enormous barriers of
679 commercialization in medical practice: no links with pharma private businesses, public and private
680 sponsorship of medical product trials is very low, which directly affects the willingness and interest
681 of medical graduates to work in the field of medical chemistry”. (I2) also laments: “TTOs are
682 bureaucrats with [the] decision-making process depending on top university officials and
683 government priorities, not necessarily on what business needs. As a researcher I will go where [the]
684 money [is] when commercializing my research, private business is much of a help”. This
685 demonstrates the importance of co-ownership on invention and direct collaboration with industry
686 (Boardman and Ponomariov, 2009)

687 Scientists reflecting on TTOs bureaucracy and inefficiencies have called for a new generation
688 of TTOs which can develop a practice-based mix of offerings and to become an information broker
689 for potential investors (Lerner, 2005)

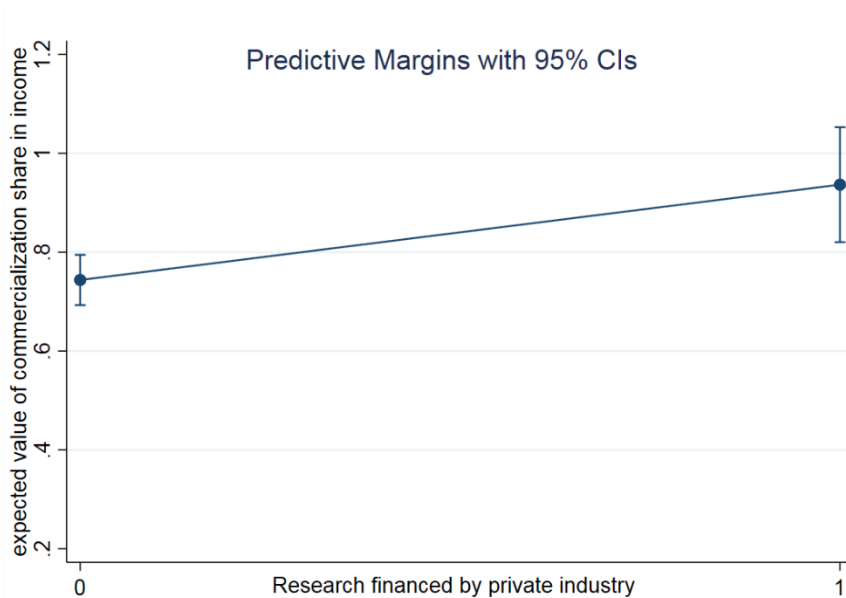
690 (I10) highlights the role of cultural factors, which could not be captured easily captured with
691 the regression model, such as the use of English language in transition economies to communicate
692 to foreigner investors and entrepreneurs. I(20) from Kazakhstan adds on the lack of networking
693 between university and business: “I have worked with a number of business schools, let’s put it like
694 that. I’ve been totally underwhelmed at what I’ve seen. I’ve been going to them to market my
695 research and because I wanted a business community. The truth is most businesses know more than
696 most business schools”.

697

698 **4.2. Direct industrial funding and university research commercialization**

699 Direct industrial funding facilitates knowledge commercialization by scientists (Bogler, 1994;

700 van Looy et al. 2004; Bozeman and Gaughan 2007).(spec 1-3, Table 4). Fig. 6 illustrates the
 701 expected value of research commercialization income under direct industrial funding (private
 702 industry).



703
 704 Figure 6: Predictive Margins with 95% CIs: Expected commercialization rate and direct industrial
 705 funding.
 706

707 Scientists who reported their external commercialization partner as industry have significantly
 708 higher level of commercialization income, supporting H2. Our findings also supports Kerr and
 709 Nanda (2009) and Aldridge and Audretsch (2011) for developed countries, when the lack of
 710 industrial funding constrains academic entrepreneurship.

711 Our interview results demonstrate that researchers do not consider TTOs to be helpful, and
 712 aim to bypass TTOs altogether by directly approaching industry direct (Link et al., 2007; Bozeman
 713 and Gaughan, 2007). (I10) stated: “I used to be very well connected to industry in Venezuela and
 714 with a few in the US, but here it has been really difficult to approach “the industry” to offer
 715 partnership due to the difficulty of communicating in English in much of the power and energy
 716 sector, which is my main area...I could, however, connect with foreign industries working in
 717 Kazakhstan, interested to adopt technology, but I have noticed they were only interested in
 718 providing services”. TTOs at university should perform a stronger broker role for investors in
 719 marketing invention (Siegel et al. 2004; Cunningham and Link 2015; O’Kane et al. (2015). As

720 suggested by I(20): “there are commercialization challenges with private industry in Kazakhstan. In
721 my opinion, the level of collaboration between science and industry is at its lowest, and in particular
722 in business and economics”. This is puzzling as while university business schools are not engaged
723 in applied research, they could become facilitators of market development and compliment TTOs
724 (Aldridge and Audretsch, 2011; Audretsch, 2014). Several interviewees commented on direct
725 industrial funding in Belarus. (I2) comments: “It is hard to connect to industry if you do not have
726 networks, however those who manage may directly own the invention or share the ownership
727 between a sponsor – private industry and a scientists”. (I2) further adds “Direct industrial funding is
728 more attractive here as it is faster, they are open and give more freedom of research and
729 experimentation, they involve you at each step of commercialization and pay royalty” (Melin, 2000;
730 Slaughter and Rhoades, 2004; Damsgaard and Thursby, 2013). Our interviews confirm that
731 scientists support the “Professor Privilege” –type system (Hvide and Jones, 2016) and wish it to be
732 adopted in transition economies.

733 734 **4.3. Other factors and university research commercialization**

735 At the individual level of university knowledge transfer model, prioritizing research over
736 teaching and commercialization results in a lower commercialization income ($\beta=-0.342-0.363$;
737 $p<0.10$), while being an associate professor increases commercialization income ($\beta=0.609-0.626$;
738 $p<0.05$) (Aldridge and Audretsch, 2011). Neither self-sponsoring research nor publication record is
739 associated with research commercialization income, which contrast negative association found by
740 Broadman and Ponomariov (2009). High number of publications may not necessarily correspond to
741 high-quality research in a transition context as most of publications target national and not
742 international peer-reviewed journals.

743 At the organizational level, university ownership is not associated with research
744 commercialization income. At the ecosystem level, university funding research does not change
745 research commercialization income. Research funding by public institutions, foreign institutions

746 and professional associations as well as academic partner institutions (outside the university) is not
747 associated with research commercialization income. Collaboration with non-for-profits increases
748 commercialization income ($\beta=1.46-1.50$; $p<0.05$), however, this type of collaboration usually
749 includes paid consultancy and volunteering work, and is not associated with technology transfer to
750 non-for-profit (Bercovitz et al. 2001).

751 Ecosystem-level formal and informal institutions in Belarus, Kazakhstan and Azerbaijan were
752 similar to each other in their impact on research commercialization income of scientists. An average
753 scientist's commercialization income in 2017 was higher than in 2015. Inverse Mill's ratios for
754 disclosure bias and commercialization active are negative and statistically significant. This
755 demonstrates that respondents who did not answer the question on commercialization and were not
756 included in our final sample were less likely to participate in commercialization activity and receive
757 an income.

758

759 **5. Discussion.**

760 Unlike factors which influence research commercialization in developed economies (Chapple
761 et al., 2005; Mustar et al., 2006; Grimaldi et al., 2011; Heinzl et al. 2013; Bradley et al. 2013)
762 forged through social capital measures and experience gained by serving on an advisory board, in
763 the transition context they do not seem to play an important role. At the same time aspects of human
764 capital such as academic position as well as personal characteristics of scientists such as age,
765 publication record have little or no effect on commercialization income, either in the US (Aldridge
766 and Audretsch, 2011) or in transition countries.

767 According to the existing literature (Thursby and Thursby, 2004; Perkmann et al. 2013;
768 Guerrero and Urbano, 2014, 2017) and in case of the troubled transition economies (Marozau and
769 Guerrero, 2016), we found that the universities' TTOs are limited in their legal and resource ability
770 to commercialize university research (Perkmann et al. 2013). Scientists at universities often treat
771 invention as a "public good" (Slaughter and Rhoades, 2004), hence the detect involvement of a

772 scientist in a start-up or spin-off is unlikely. In contrast, private industry funds research it has
773 already identified to have high potential for commercialization. Since private industry pays for the
774 research it has an interest in adopting it as well as maintaining the legal ownership of research
775 outcomes (Broadman and Ponomariov, 2009). U

776 Our finding demonstrates that direct industrial funding is the most efficient route of research
777 commercialization by scientists as compared to disclosure, marketing and adaptation of technology
778 via TTOs. We contend that TTO activity and direct industrial funding are not two successive steps,
779 but may perform as two alternative models of knowledge transfer . This is an unexpected and
780 interesting finding, which emphasizes the role of inventor-ownership on research outcomes in
781 transition economies. The implementation of inventor-ownership mechanism in transition
782 economies is challenging. This will require legal changes (e.g. IP regulation, co-ownership),
783 creating university environment which is supportive to entrepreneurial activities (e.g. adjustment in
784 teaching load, academic leadership and citizenship, funding conferences, academic visits, guest
785 lectures, applied research and dissemination activities) (Kenney and Goe, 2004), in particular, TTOs
786 should be granted greater independence from university and their leaders to be given more
787 economic incentives to become a conduit of knowledge transfer.

788 To date, TTOs have become neither facilitators nor promoters of knowledge transfer and
789 knowledge spillover from universities. This challenges the legitimacy of TTOs (O’Kane et al.,
790 2015) as centres of knowledge transfer. Kenney and Patton (2009) found the system under which
791 universities maintain the legal ownership of inventions is less than optimal in terms of economic
792 efficiency and in advancing the private interests of commercialization. Our finding confirms it for
793 transition economies.

794 We propose three alternatives that would address the current lack of scientists’ engagement in
795 research commercialization in transition contexts.

796 Our first proposal is to vest ownership with the inventor in a spirit of the “Professor Privilege”
797 system. Investors should be free to contract with the university TTO or any other entity outside the

798 university to support research commercialization. Inventor-ownership system was suggested by
799 Kenney and Patton (2009) and in recent works by Czarnitzki et al (2015, 2016) who found that
800 transition from an inventor-ownership to a university-ownership model decreased both the volume
801 and quality of patented inventions by university professors. Hvide and Jones (2016) found that the
802 abolishment of "Professor's Privilege" in Norway led to about a 50% drop in the rate of start-ups by
803 university researchers. Policy makers who presumed that costs and risks of patenting and starting a
804 business were too high for individual inventors appeared to be wrong.

805 Our second proposal is to sponsor open access to university research through public funds,
806 without an exclusive right of a public sponsor, or a university, on research results in any sector and
807 any university type. All inventions will be further contracted by the TTO if the establishment of a
808 legal relationship to further expand and validate the inventions is required by industry. It is also
809 important that all inventions should be licensed freely and non-exclusively. Unless sponsored
810 directly by private industry, neither universities TTO nor other public sponsor may hold exclusive
811 ownership of inventions (Powers and McDougall, 2005; Audretsch, 2014; Shu et al. 2014).

812 Our third proposal is to support TTO's brokerage between junior university scientists and
813 industry (Perkmann et al., 2013). Junior scientists have less experience in marketing technology to
814 private industry and work with early stage technologies may benefit most by disclosing their
815 inventions to TTOs as the earlier stage of technology development (Lerner, 2005).

816 Interviewee (I20) contributed to this discussion: "We need a commercialization platform to
817 engage researchers right through the university to industry. This is private industry which needs to
818 dictate [to] TTOs what problems need to be solved and what would they like to improve". These
819 measures will enhance participation of ecosystem stakeholders and TTOs in knowledge transfer.
820 Various crowdfunding platforms and angel investor funds have been established in collaboration
821 with the business schools in developed economies (Guerrero and Urbano, 2012, 2014; Belitski and
822 Heron, 2017). If current structures cannot be created with the current competences on the basis of
823 TTOs in transition economies, scientists, in particular more mature and with late-stage technologies

824 will continue to bypass TTOs (Link et al., 2007). A new generation of TTOs should be integrated
825 within business schools structures with private ownership on invention in case of successful
826 fundraising . Finally, the effect of university support mechanisms should be more decisive (Kenney
827 and Goe, 2004; Kwiek, 2012). “What makes a die-hard academic entrepreneur?” with 15 years
828 overview of the academic entrepreneurship and knowledge transfer literature, the answer is very
829 different to scientist entrepreneurs in transition economies.

830

831 **6. Conclusions.**

832 By asking scientists rather than university TTOs (Caldera and Debande, 2010) about the
833 entrepreneurial activities they engage in and their commercialization income, a clear picture
834 emerges for the research commercialization in transition economies. Firstly, a number of
835 indications suggest that there is no relationship between the establishment of TTOs, TTO
836 awareness, the number of contracts signed via a TTO and the extent of research commercialization.
837 The former is not associated with individual characteristics such as scientist age, research output
838 and quality or the self-sponsorship of research. Secondly, direct industrial funding is an effective
839 conduit of knowledge transfer and knowledge spillover from universities , which may function as a
840 substitute for public and angel finances. It is important that ownership is shared between an inventor
841 and industry. Thirdly, the extent of research commercialization is less organisationally embedded
842 and more ecosystem embedded with direct industrial funding plays the leading role in research
843 commercialization (Boardman and Ponomariov, 2009; Grimaldi et al., 2011; Miller et al. 2014; Acs
844 et al. 2017).

845 The empirical results from this study also suggest that more scientists engage in research
846 commercialization in transition economies than in the US (Aldridge and Audretsch, 2011);
847 however, only 13 percent of them are paid for knowledge transfers. This study makes the following
848 contributions to academic entrepreneurship, entrepreneurship ecosystems and the KSTE literatures.

849 First, adopting the TTO perspective of the KSTE and the stakeholder perspective to
850 entrepreneurship ecosystem framework, we investigate research commercialization by scientists in
851 transition economies controlling for individual, university and ecosystem characteristics. The
852 empirical results suggest, that commercialization income does not exactly mirror what has been
853 found in the literature on academic entrepreneurship in developed economies (Wright et al., 2006,
854 2007; Kenney and Patton, 2005, 2009; Aldridge and Audretsch, 2011; Perkmann et al., 2011a,
855 2013).

856 Secondly, we develop a multi-level model of university research commercialization , which
857 jointly examined the role of TTOs and direct industrial funding capital as a conduit of knowledge
858 transfer from university in transition countries.

859 Thirdly, using unique primary data on scientists' entrepreneurial activity in three transition
860 economies and controlling for various selection biases, this study provides important evidence for
861 users / investors of academic research in transition economies. We demonstrate that university
862 TTO, unlike direct industrial funding, has not yet become a conduit for knowledge transfer and
863 spillover (Audretsch, 2014).

864 Responding to a call in the academic entrepreneurship literature (Kenney and Patton, 2009;
865 Grimaldi et al. 2011; Aldridge and Audretsch, 2011), this study identifies the determinants of
866 university research commercialization across a broad spectrum of scientific fields, sizes, types of
867 universities and in a different socioeconomic context. Whether this finding holds across broader
868 groups of developing and transition economies as well as across more specific scientific fields and
869 ecosystem stakeholders is an important issue that will be addressed in future research.

870 Subsequent research needs to identify the prevalence and multi-level determinants (Perkmann
871 et al. 2013; Guerrero and Urbano, 2013) of a variety of research commercialization models, such as
872 establishing a spin-off, corporate entrepreneurship, paid consultancy and other (Muscio, 2010;
873 Siegel et al. 2007; Kenney and Patton 2009; Abreu et al. 2016; Kolympiris and Klein, 2017). What
874 particular organizational and ecosystem characteristics as well as scientist's capabilities that

875 facilitate interactions with the industry, foreign firms, government and TTOs? Given a very limited
876 functions of TTOs in transition economies, it is unlikely we can expect any substantial effect of
877 TTO activity on the valorization of research results. Implementation of the multi-level academic
878 entrepreneurship ecosystem framework in future research (Perkmann et al. 2013; Acs et al. 2017)
879 could be an answer to how research commercialization could be better facilitated by a variety of
880 entrepreneurial ecosystem actors. It is also important to find an entrepreneurship ecosystem locus
881 (city, region, country) with characteristics which are strongly associated with scientists' decision-
882 making to commercialize research.

883

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1151 **Appendix A**

1152
1153 Table A1: The list of universities participated in the survey and interviews
1154

Country	Institution	Webometrics ranking of University	Pre-1991 University	Technical University	TTO established
Belarus	Belarusian State University	1	Yes	No	Yes
	Belarusian State Economic University	9	Yes	No	No
	Belarusian National Technical University	2	Yes	Yes	Yes
	Belarusian State University of Informatics and Radioelectronics	5	Yes	Yes	Yes
	Polesky State University	11	No	No	No
	Polotsk State University	16	Yes	Yes	No
	Belarusian State Technological University	6	Yes	Yes	Yes
Belarusian State Agricultural Academy	30	Yes	No	No	
Kazakhstan	Nazarbayev University	5	Yes	Yes	Yes
	Kazakh-British Technical University	11	Yes	Yes	Yes
	KIMEP University	9	No	No	Yes
	Kazakh National Technical University	3	Yes	Yes	Yes
	Narhoz University	9	Yes	No	Yes
	Turan University	54	No	No	No
	Akhmet Yassawi International Kazak-Turkish university	n/a	No	No	Yes
	Innovative Eurasian University	35	No	No	Yes
Azerbaijan	Baku State University	1	Yes	Yes	Yes
	Azerbaijan University of Architecture and Construction	13	Yes	Yes	No
	Baku Engineering University	5	No	Yes	Yes
	Khazar University	3	No	No	No

1155 Source: Webometrics Ranking of World Universities available at: <http://www.webometrics.info/en/> and
1156 university website information.
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1159 Table A2: Selection models.

<i>Two-step Heckman approach</i>	Model 1: Disclosure=1			Model 2: Active=1		
	dx/dy	SE	Marginal effects	dx/dy	SE	Marginal effects
Age (log)	1.01	0.38***	3.71	0.26	0.29	3.71
Researcher=1, 0 otherwise	0.24	0.25	0.14			
Ass. Professor=1, 0 otherwise	-0.34	0.21*	0.35			
Full professor=1, 0 otherwise	-0.16	0.30	0.18			
Comm. activity: consulting=1, 0 otherwise	-0.03	0.22	0.19			
Comm. activity: honorarium=1, 0 otherwise	0.28	0.19	0.33			
Comm. activity: establishing spin-off=1, 0 otherwise	-0.49	0.41	0.08			
Comm. activity: licencing patents=1, 0 otherwise	0.57	0.37*	0.06			
Comm. activity: product sales=1, 0 otherwise	-0.17	0.24	0.18			
Comm. activity: public grants=1, 0 otherwise	0.03	0.18	0.53			
Comm. activity: multiple=1, 0 otherwise	-1.09	0.22***	0.43			
Research financed by university=1, 0 otherwise				-0.19	0.21	0.18
Research financed by foreign grants=1, 0 otherwise				0.89	0.34**	0.13
Research financed by government grants =1, 0 otherwise				0.39	0.20**	0.34
Research financed by private industry=1, 0 otherwise				0.27	0.34	0.08
Research self-financed=1, 0 otherwise				-0.35	0.19*	0.35
Private university=1, 0 otherwise				0.27	0.19	0.24
Country dummies (reference country=Azerbaijan)		Yes			Yes	
Year dummies (reference year=2005)		Yes			Yes	
Number of obs.		2602			424	
Likelihood ratio test Wald chi2		47.5			36.28	
Prob > Chi2		0.00			0.00	
Pseudo-R2		0.126			0.100	

1160 Note: Marginal effects and robust standard errors from probit regression model are shown. ***, ** and * Significance at the 1%, 5% and
1161 10% levels, respectively. Both models include year controls, which are jointly significant. Model 1 and Model 2 the inverse Mills ratios
1162 calculated are used on the final stage to predict commercialization share. Reference category for commercialization activity=multiple
1163 commercialization activity. Reference category for commercialization activity=multiple commercialization activity. Reference category for
1164 research financing= multiple sources of finance.
1165 Source: Academic entrepreneurship survey data for Belarus, Kazakhstan and Azerbaijan (collected 2015, 2016 and 2017).
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Table A3: Mixed-effects GLM: Country and university level effects on scientist's research commercialization activity. DV: Commercialization share in income standardized [0,1]

Specification	(1)	(2)	(3)	(4)	(5)	(6)
Dep. variable distribution	Binomial			Bernoulli		
Constant	1.149*** (0.21)	1.167*** (0.16)	1.167*** (0.16)	1.169*** (0.17)	1.167*** (0.16)	1.167*** (0.16)
Variance (country level)	0.0604 (0.11)			0.01 (0.07)		
Variance (university level - size)		0.00 (0.00)			0.00 (0.00)	
Variance (university level - ownership)			0.00 (0.00)			0.00 (0.00)
N	272	272	272	272	272	272
LR test vs. logistic model (chi2)	0.77	0.00	0.00	0.01	0.00	0.00
p-value (chi 2)	0.18	0.98	0.98	0.18	0.98	0.98
Log-likelihood	-150.33	-120.03	-120.03	-120.03	-120.03	-120.03

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Note: Number of obs. 272 researchers. ***, ** and * Significance at the 1%, 5% and 10% levels, respectively.
Source: Academic entrepreneurship survey data for Belarus, Kazakhstan and Azerbaijan (collected 2015, 2016 and 2017).

1174 Appendix B1: List of interviewees included in this study

position	age	experience, years	Field of science	comm. activities	external funding	comm. share in income	external partners on commercialization	university ownership	country	Collaborate with TTO?
associate professor	64	10	engineering	product sales (without spinoff), public grants, consulting, honorarium	private industry capital	60	industry	public	BY	No
assistant professor	27	1	social	public grants, honorarium	foreign grants, university	30	other academic institutions, foreign institutions, other for profit and non-for-profit	public	BY	No
research fellow	31	8	economics	establishing a spin-off, product sales (without spinoff), public grants	government grants, foreign grants, private industry capital	80	other academic institutions, foreign and public institutions, industry, profit and non-for-profit	private	BY	Yes
research fellow	60	39	chemistry	licencing patents, public grants, consulting, honorarium	government grants	2.6	other academic institutions, foreign institutions, industry, other for profit and non-for-profit	public	BY	Yes
full professor	66	47	economics	product sales (without spinoff), public grants, honorarium	foreign grants, university	10	other academic institutions, foreign institutions, industry	public	BY	Yes
full professor	60	35	economics	product sales (without spinoff), public grants, consulting, honorarium	foreign grants, university	10	foreign institutions, industry	public	BY	Yes
associate professor	37	15	economics	public grants, honorarium	government grants, university, self	5	other academic institutions, foreign institutions	public	BY	No
associate professor	33	6	social	honorarium	university, self	2	foreign institutions	public	BY	No
assistant professor	35	8	social	consulting	university	1	public institutions, industry, other for profit and non-for-profit	public	BY	Yes
associate professor	51	27	engineering	licencing patents	private industry capital	25	foreign institutions	public	KZ	Yes
full professor	57	32	engineering	public grants	government grants	30	other academic institutions	public	KZ	No
full professor	57	36	biosciences	honorarium	university	80	Private Industry	public	KZ	No
assistant professor	26	4	economics	public grants	government grants	15	foreign institutions	private	KZ	No
full professor	64	40	food	multiple	government grants	10	Private industry	private	KZ	Yes
full professor	56	27	economics	product sales (without spinoff), public grants, consulting	government grants, self	10	public institutions, industry	private	KZ	No
full professor	50	20	law	public grants, honorarium	government grants, university, self	10	other academic institutions	private	KZ	No
full professor	47	27	physics & math	licencing patents, public grants, honorarium	foreign grants, university, self	1	other academic institutions, foreign institutions, industry and professional associations, for profit and non-for-profit	private	KZ	No
full professor	61	37	economics	public grants, honorarium	government grants, university, self	30	other academic institutions	private	KZ	Yes
full professor	60	36	medicine	establishing a spin-off, product sales (without spinoff), public grants, honorarium	government grants, foreign grants	30	other academic institutions, foreign and public institutions, other for profit and non-for-profit	private	KZ	No
assistant professor	40	5	engineering	licencing patents, product sales (without spinoff), public grants	private industry capital, university	30	Private industry	private	KZ	No

full professor	69	35	chemistry, medicine	public grants, honorarium	government grants, foreign grants	50	other academic institutions, foreign institutions	public	KZ	No
associate professor	35	10	medicine	public grants, honorarium	government grants, self	3	other academic institutions, foreign institutions	public	KZ	Yes
full professor	50	27	biosciences	establishing a spin-off, public grants	government grants	10	other for profit and non-for-profit	private	KZ	No
research fellow	37	15	engineering, physics & math	establishing a spin-off, product sales (without spinoff), public grants, consulting	government grants, private industry capital, university	25	other academic institutions, public institutions, , industry, other for profit and non-for-profit	public	AZ	Yes
associate professor	36	10	economics	public grants, consulting	foreign grants, private industry capital	40	foreign institutions, industry and professional associations	public	AZ	No
associate professor	42	20	economics	establishing a spin-off, product sales (without spinoff), public grants, consulting, honorarium	foreign grants, private industry capital, affiliated university, self	20	other academic institutions, industry and professional associations, industry, other for profit and non-for-profit	private	AZ	Yes
research fellow	33	6	social	licencing patents, establishing a spin-off, product sales (without spinoff), public grants, consulting	foreign grants, private industry capital	5	foreign institutions	private	AZ	Yes

Note: Interviewee names are not disclosed.

Source: Academic entrepreneurship in Belarus (BY), Kazakhstan (KZ) and Azerbaijan (AZ) project interviews

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1176

1177 Appendix B2. Interview Protocol

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1179 **Background and Overview of the researcher**

1180 Please note, *before the interview*, the interviewer may be able to gather much of the data for this
1181 section from the participating respondent. In fact, it is strongly recommended collecting this data as
1182 soon as possible, as these data are important for drawing inference across field of research, type of
1183 commercialization, partner in research commercialization and respondent's individual
1184 characteristics.

1185 **Eligibility criteria to participate in this interview. Please confirm:**

- 1186 1. You commercialise knowledge and technology created at the university (Yes/No).
1187 2. You are actively involved in any of the research commercialization activity (e.g.
1188 establishing a spin-off, product sales (without spinoff), public grants, consulting, honorarium) with
1189 a share of commercialization in total income greater than zero (Yes/No).
1190 3. Your research is sponsored by at least one external collaboration partner (e.g. university,
1191 government, foreign, private industry in addition to self-sponsorship if any) (Yes/No).

1192 Interview questions

- 1193 • What is your name? What is your position at university?
1194 • How many works have published over the last 5 years, including industry publications with
1195 practitioners?
1196 • What is your field of research? What is a secondary or complementary field of research?
1197 • Do you know if any of your academic colleagues commercialize their research?
1198 • Can you say that your university and country business environment is friendly towards the
1199 idea of academic entrepreneurship?
1200 • Do you feel an increase of research to teaching ratio would increase your commercialisation
1201 capacity and income and why?
1202 • What barriers do you face in commercializing your research from the department/ faculty
1203 level, from university level, from business environment?
1204 • What is the most substantial source of commercialization of your research from the
1205 following licensing of the patents, running spin-off company, selling products without starting spin-
1206 off, getting grants, consulting activity, getting honorarium for books, conferences, lectures other?
1207 • In case of positive commercialization we ask: How do you protect your IP?
1208 In case of no commercialization we ask: If you were to start an own business to commercialize your
1209 research what are the factors which prevent you from this: financial (economies of scale, taxes) ;
1210 administrative and institutional (corruption, doing business conditions), external support or no
1211 support (venture and angel investors, crowdfunding, etc.)
1212 • What do you think should be done to enable researchers establish own business (Spinoffs)?
1213 • Please name one or two preferred external partners in commercialization of your research?
1214 • How often do you collaborate with Technology transfer offices (TTO) at your university?
1215 • What are the major challenges you experience when collaboration with TTO?
1216 • What could be improved in the work of TTO to make them more effective?
1217 • Should TTO be a middleman (entrepreneur) between you and a company interested in your
1218 research? Who is there instead of TTO to help you linking to business (techno parks, incubators,
1219 business networks, professional association, etc.)?
1220 • Please list one or two most important external sponsors for your research
1221 • Would you like to name few recommendations, which in your opinion, could be quickly
1222 implemented by policy-makers and university administration? _____
1223 *We thank you for your time and collaboration.*