Internationalizing-Innovation Profiles and High-Technology Exports: Does Lone Genius Matter?

Monte J. Shaffer, Kevin Chastagner, and U.N. Umesh

ABSTRACT

Innovation-performance research, when conducted at the firm level, neglects the role of innovation that is created without firm involvement. In this article, the authors test Schumpeter's lone-genius hypothesis: "Change in economic life always starts with the actions of a forceful individual." To do so, the authors introduce country-level internationalizing-innovation profile (IIP), which characterizes a country's innovation resources, and internationalizing-innovation experience (IIE), which characterizes a country's level of patenting activity into the United States. Using fixed-effects panel data analysis for 50 countries from 1990 through 2010, the authors demonstrate that a country's IIP moderated by IIE influences high-technology exports. The findings suggest that lone genius does have an impact, depending on the phase of a country's IIE development. The implications of these findings for theory, public policy, and international marketing managers are discussed.

Keywords: innovation, internationalization, export performance, high technology, patents, panel data analysis

The practice of deploying innovations into international markets has strategic relevance for firms engaged in exporting high technology and for countries that support such high-technology commercialization processes. Research across disciplines has documented the positive relationship of innovation deployment with both a firm's performance (e.g., Tellis, Prabhu, and Chandy 2009) and a country's economic growth (e.g., Fagerberg, Srholec, and Verspagen 2010). Innovation-performance research endeavors to understand *how* deployed resources embedded in high technology lead to favorable market outcomes. In his theory of economic development, Schumpeter (1942, p. xi) argues that such favorable "change in economic life always starts with the actions of a forceful individual and then spreads to the rest of the economy." Anchored to this premise, we posit that the lone genius (a single-author inventor who creates high technology without a firm's involvement) may generate better ideas that lead to the creation of better technology, which in turn will prompt positive market acceptance and ultimately contribute to a country's economic development.

On the basis of our review of the literature, we conclude that Schumpeter's lone-genius hypothesis (i.e., the "heroic intervention of individual entrepreneurs toward new economic shores") has not been fully investigated. First, firm-level research does not include lone-genius innovations in the analysis. As such, understanding how lone-genius innovations compare with innovations traditionally studied within firms is an important gap that needs to be filled. By disregarding lone-genius creations, innovation-performance research may omit important

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factors for a country's economic development. Second, prior innovation-performance research has not considered the influence of lone genius in the internationalizing context (i.e., toward new economic shores). For example, Singh and Fleming (2010) limit their analysis to innovations "arising from U.S.-based inventors" (p. 46) yet conclude that "the heroic [intervention] … could be a myth" (p. 55). Such restrictive analysis has muddled rather than clarified the role of the lone genius. Are U.S.-generated innovations the same as innovations developed internationally for export into a foreign market? The study of new economic shores as a literal external market is an important research gap that merits further examination. Such research would enable generalizable conclusions of the lone-genius hypothesis according to a country's innovation experience. We endeavor to extend previous research by examining, at the country level, how innovation development in the internationalizing context influences export performance. Such analysis enables us to investigate facets of the innovation-discovery process that may exist outside of the scope of firms, specifically, the lone genius.

The primary objective of this research is to thoroughly investigate Schumpeter's lone-genius hypothesis. To do so in a precise manner, we emphasize three key points regarding lone-genius innovations: (1) a single author inventor creates the high technology, (2) this inventor creates the high technology without a firm's involvement, and (3) the high technology is exported to international markets. To identify lone-genius innovations, we therefore specify innovation profiles at the country level that indicate *who* creates the innovation, *how* the creation team is involved with firms during the discovery process, and *how much* technology is specified in the innovation. We examine the influence of these innovation profiles on high-technology exports for 50 countries from 1990 through 2010. Collectively, this framework allows us to study the influence of lone genius on the development and deployment of internationalizing innovation.

Our study makes three important contributions. The first contribution is a careful examination of lone-genius innovations in the internationalizing context, which enables us to address two important questions: (1) Does lone genius influence a country's high-technology exports? (2) If so, does this influence change as a country's experience with internationalizing innovation matures? We address these questions more rigorously than prior research in that we conceptualize lone-genius innovations more precisely. That is, our definition of lone genius is a specific interaction of two fundamentally independent characteristics: a single-member team and no firm involvement. Anchored to this deconstruction, we define innovation profiles by abstracting the lone-genius characteristics into resource classifications: the nature of the innovation team and the degree of firm involvement.

The second contribution is the development of a resource–experience–performance framework to compare different countries' approaches to internationalizing innovation. Such a framework requires measurement equivalency; that is, the measured characteristics must be the same across countries. To achieve measurement equivalency, we examine the performance of each country's high-technology exports according to comparable resource and experience attributes of within-country high technology. We utilize a country's patent portfolio to ascertain the resources and experience associated with the high technologies being exported. Critical for our purposes, internationalizing innovation requires that the intellectual property (i.e., patents) associated with a technology be procured in the country where the monopolistic position (i.e., exclusionary rights) is to be secured (Jain 1996). For example, an international marketing manager in Singapore who wants to export high-technology products must obtain intellectual property protection for such technology in each country where a market presence is desired. To ensure comparability of internationalizing innovation across countries, we choose to observe the characteristics of 50 countries' patent portfolios for a single external market, the United States (which represents the largest global market), from 1990 through 2010.

Our study's third contribution is the way in which we profile countries according to comparable resource-contingency characteristics. Such a resource-based perspective is congruent with recent international marketing studies that link different forms of resource configurations to export performance (e.g., Lages, Silva, and Styles 2009; Leonidou et al. 2013; Navarro et al. 2010). We apply prior resource perspectives to country-level analyses by considering a country's overall experience with patenting high technology into the United States and by profiling the potential embedded in the country's high-technology patent portfolio. This also enables us to demonstrate how experience moderates the relationship of a country's innovation profile to its high-technology exports.

The remainder of this article is organized as follows. First, we review pertinent literature to advance our conceptual framework and develop generalizable hypotheses. Next, we summarize the data and measures, develop appropriate models to test our hypotheses, and report our regression results. Finally, we discuss our study's theoretical contributions and policy and managerial implications, its limitations, and directions for future research.

CONCEPTUAL FRAMEWORK

The resource-contingency perspective (Slotegraaf, Moorman, and Inman 2003)—that is, the idea that a firm must not only acquire resources but also deploy these resources—has had broad applications within the field of marketing since its introduction. Slotegraaf and colleagues point out that not all resources are equally valuable in the deployment process and conclude that intangible marketing resources configured with technological capabilities embedded in patents may be more important than financial resources. We posit that the resources under a firm's control are deployed to advance the firm's product-market strategy (Penrose 1959) according to its technical capabilities and go-to-market capacities (Moorman and Slotegraaf 1999). Congruent with this resource-contingency perspective, we define exporting as the actionable deployment of available resources to take products to foreign markets. In the internationalizing context of exports, firms need the ability to dynamically recombine resources in response to technological advancements and market developments.

Drawing on this resource–deployment–performance premise, some scholars have adapted firm-level resource perspectives for country-level analyses. Analogous to firms, countries represent entities that can leverage resources for international competitiveness (Jackson and Deeg 2008; Tellis, Prabhu, and Chandy 2009; Wan 2005). The country-level analysis of exports looks at portfolios of firms deploying technological resources in go-to-market strategies. In our representation of internationalizing innovation, experience and resources embody the aggregation of all such firm-level activity within a country.

Innovation Development and High-Technology Export Performance

High technology represents the novel application of scientific knowledge in the development of products and services. As Sood and Tellis note, "technological change is perhaps the most powerful engine of growth" (Sood and Tellis 2005, p. 152), and it may be the essential driver in "promoting the global competitiveness of nations" (Sood and Tellis 2009, p. 442). As such, high technology is at the vanguard of both technology and products. The creation of high technology presents an opportunity for unprecedented fulfillment of customer needs (Chandy and Tellis 1998) and empowers stakeholders with the potential to drive markets (Kumar, Scheer, and Kotler 2000). That is, the potential that exists with the creation of high technology generates opportunities for commercialization.

Internationalizing innovation refers to the creation of high technology in a home country for deployment to a foreign market. Usually, firms are studied in this context because they represent vehicles for commercialization into foreign markets (Leonidou and Katsikeas 2010). However, creators of innovations can be found beyond traditional firm boundaries. Therefore, we apply a resource-based perspective to a country-level analysis so that we can measure the impact of innovation creation outside of traditional firm boundaries. To do so, we develop a country's internationalizing-innovation profile (IIP) on the basis of key features of its patent portfolio. The IIP for a given year represents an aggregate of all patented technologies secured in that year, according to three types of resources—human capital (*who*), organizational capital (*how*), and physical capital (*how much* property)—that can be deployed in foreign markets for economic gain (Barney 1991; Wernerfelt 2014).

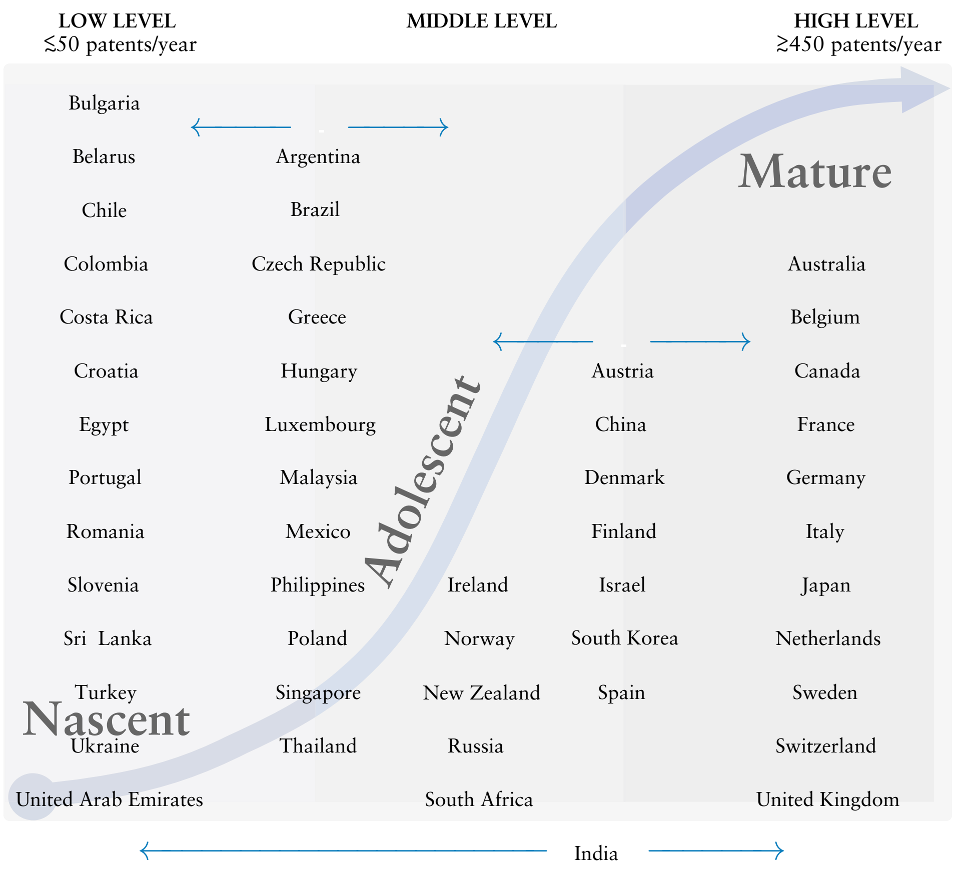
Experience Deploying High Technology

We also examine the role that a country's experience with the development of innovation for internationalization has with regard to the country's export performance. We posit that experience moderates performance in general (Hultman, Katsikeas, and Robson 2011) because experience breeds more experience (Griffith, Yalcinkaya, and Rubera 2014). Applying this to our framework, we expect that internationalizing-innovation experience (IIE), which represents a country's overall experience with patenting high technology into the United States, will moderate the impact of IIP characteristics on a country's high-technology export performance. As stakeholders in the innovation-export system gain experience by creating technology, securing the technology, and commercializing the technology, they learn more about the process, and this allows them to better understand the potential opportunities for further learning (Zahra, Ireland, and Hitt 2000). Furthermore, as stakeholders within the innovation-export system gain experience, they provide indirect learning opportunities for the other stakeholders (Banerjee, Prabhu, and Chandy 2015). This systematic building of experience can be represented by an S curve with three distinct phases: nascent, adolescent, and mature.

The first phase (nascent) represents initial IIE growth as stakeholders enter the fray and learn how to be successful in exporting innovation. During this phase, a country has both limited exposure to and limited experience with the process of internationalizing innovation. The second phase (adolescent) represents a coming of age for countries as their developing capacities for innovation become institutionalized: more stakeholders move into the experience system, indirect learning builds as knowledge spills over, and the experience compounds within the system. This phase, which can be represented as the inflection point along the S curve, embodies a transition from the nascent phase to the mature phase. The third phase (mature) represents saturated growth as the inertia from existing opportunities impedes new opportunities: procedures for securing patents in the United States have been well defined, international marketing managers have developed go-to-market strategies, and trade relationships have been refined. The incumbent capacities of these embedded systems hamper new system development.

In Figure 1, we summarize country membership within these three IIE levels from 1990 through 2010. For a given year, we operationalize the IIE framework through a tercile split of international patenting activity into the United States. Although it may be possible for a country's

Figure 1. Levels of IIE



Notes: For a given year, we perform a tercile split of the number of patents granted by each country to classify them as low level (≲50 patents a year), middle level, and high level (≳450 patents a year). The first column lists countries (e.g., Bulgaria) that experienced only a low level of IIE between 1990 and 2010. The second column lists countries (e.g., Argentina) that experienced two levels of patenting activity (low and middle). The third column lists countries (e.g., Ireland) that experienced only a middle level of IIE. The fourth column lists countries (e.g., Austria) that experienced two levels of patenting activity (middle and high). The fifth column lists countries (e.g., Australia) that experienced only a high level of IIE. India experienced all three levels (low, middle, and high).

IIE to contract rather than expand, we only observe an evolutionary process in our data: from nascent (low level) to adolescent (middle level) to mature (high level). We observe that India is the only country that can be classified at all three levels of patent activity during this 21-year time frame. Many countries (e.g., Brazil) experienced low and middle levels of patenting activity, while others (e.g., China) experienced middle and high levels. Still other countries (e.g., Russia) maintained one level of patenting activity across time (middle, in the case of Russia).

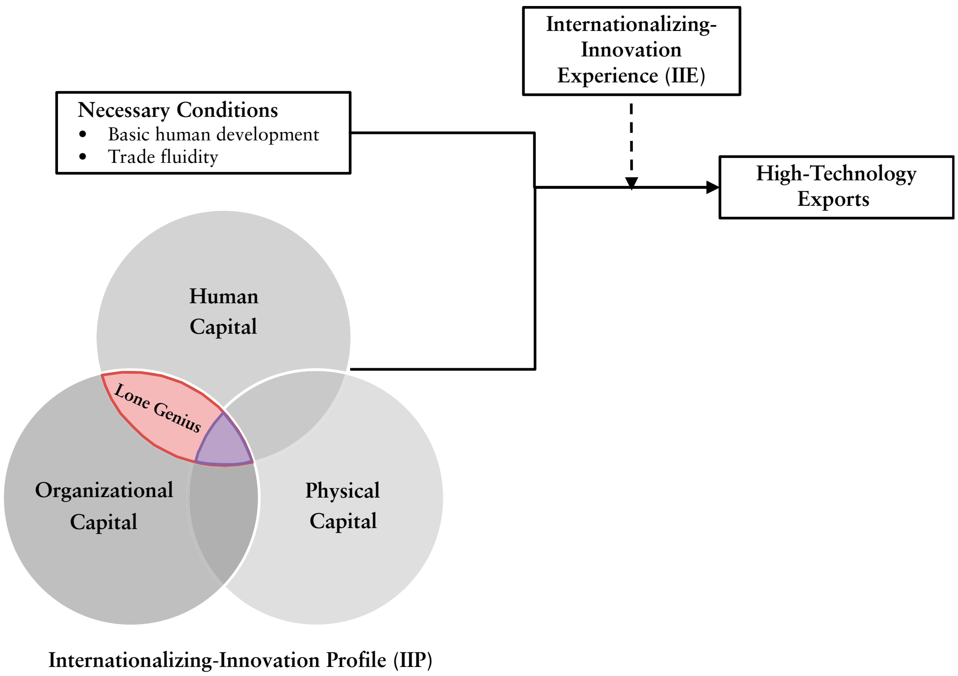
Conceptual Model

In Figure 2, we summarize the thesis of our generalizable resource–experience–performance framework: a country's IIP represents resources that, together with the country's IIE, influence its high-technology exports. In this conceptual model, we posit that three elements influence a country's international deployment of high technology: necessary conditions, the country's IIP, and the country's IIE. First, we control for countries' varying degrees of basic development. We posit that two factors represent necessary, but not sufficient, conditions for high-technology exports: basic human development (health, access to education, and a decent standard of living), which provides a foundation for the creation of innovation, and trade fluidity, which provides a vehicle for commercializing an innovation in external markets. Next, we represent a country's IIP as a Venn diagram to emphasize that resource contingencies are combined into country-level aggregates of primary resource types; that is, these types of capital overlap and intersect in unique country-level configurations. Finally, we posit that IIE moderates the influence of a country's IIP on high-technology export performance. Using this conceptual framework, we proceed to develop hypotheses about IIP configurations and a country's export performance.

HYPOTHESIS DEVELOPMENT

In the development of our conceptual framework, we advance the idea that the resources that are deployed may result in favorable market outcomes. Specific to our study of internationalizing innovation, the deployment of resources represents an innovation-commercialization process in which the creation of exceptional high technology snowballs into market success: (1) the innovation team solves a problem in an unprecedented way, (2) the solution intrinsically generates attention, (3) the attention

Figure 2. Conceptual Model



leads to consideration of commercialization avenues into foreign markets, (4) these avenues define product development and deployment, and (5) such deployment fulfills unmet market needs, resulting in above-average sales.

Within this resource–deployment–performance framework, we classify each country's IIP as three types of resources at the country level: human capital, organizational capital, and physical capital (Barney 1991). We proceed by advancing hypotheses for each of these resource types.

Human Capital (Agent of Creation)

The innovation team, which represents a type of embedded resource, encapsulates the knowledge stores needed for high-technology creation and defines the creative genius behind the innovation. As the agent of creation, the innovation team initiates the innovation-commercialization process. We define human capital in the context of internationalizing innovation as those who are directly involved with the conception of the high technology, and we use patent authorship to determine the innovation team. Although a breakthrough discovery may have transpired within an R&D group, a new product development group, or some other cross-functional team, the actual solution to the problem that creates the new high technology generally comes from a small team that conceived and maintains claims to the intellectual property described in the patent (United States Patent Office 2015).

We classify innovation teams according to inventorship of a patented technology, as follows:

- TEAM = sole inventor: a single-author inventor;
- TEAM = regional: a team with multiple inventors within the same geographic region (reference category); and
- TEAM = multiregional: a team with multiple inventors in multiple geographic regions.

Thus, the nature of the innovation team is a function of the number of inventors and their geographic distribution. A country has a portfolio of patents in its annual IIP, and as such, portions of its portfolio can belong to each of the three innovation team classifications. Because the average patent in the sample has two or three inventors, we presume that the regional team represents the default resource manifestation; these inventors live in the same city (and likely work in the same office). We develop hypotheses about innovation teams that vary from this norm: sole inventors and multiregional teams.

Because ideation is the genesis of the innovation-commercialization process, it is important to outline how breakthroughs emerge from an innovation team. Anecdotally, many knowledge workers note that the moment of discovery happens not when they are focused on the problem but rather when they are engaged in commonplace activities such as taking a shower or driving a car. Kaufman (2013) summarizes current neuroscience research on how such creative breakthroughs may occur and outlines four stages of the discovery process: preparation, incubation, illumination, and verification. An individual must manage three different mental networks to get into a creative flow: executive attention (mental focus based on subject-matter expertise), imagination (making associations between seemingly unassociated things), and salience (switching attention between external events and internal streams of cognition). During the preparation stage, an individual must free his or her mind by silencing the inner critic and lowering executive attention. During the incubation stage, the individual must increase imagination and salience engagement. If illumination (i.e., the Archimedean "Eureka!" moment) occurs, the individual must be able to immediately verify the discovery by (1) reactivating executive attention to cognitively imprint the discovery, (2) evaluating its merit, and (3) considering its implementation.

Overall, the ability to create high technology requires these knowledge workers to integrate idiosyncratic mental networks with unique problem-solving skills and thinking-style preferences (e.g., logical, verbal, visual) to foster the creative flow (Gardner 2011; Gladwell 2008). Intrinsically motivated, they intentionally develop creativity-enhancing habits to achieve breakthroughs (Gruber 1986). These divergent indicators of creativity are antithetical to normative routines established within groups and organizations.

Sole Inventor. We posit that a sole inventor will be better at creating exceptional high technology than a regional team (the reference category). A regional team represents a group that engages in collaborative activities to foster synergies from the mental networks of each member, and this introduces complexities into the ideation process. Cognitive interference and social inhibition (Paulus 2000) will impede creativity among members of the group unless they are carefully managed (Levi 2016; Thompson 2013). For the sole inventor, these inhibitors do not exist. The sole inventor can ideate in a self-directed, autonomous fashion (Dahlin, Taylor, and Fichman 2004) to suit the peculiarities of the individual's mental networks. Without normative constraints, an individual will generate more and higher-quality ideas than if that individual were engaged in ideation within a group. Better ideas have more potential for market success. Therefore,

> H_{1a}: A country's proportion of sole inventors is positively related to that country's high-technology exports.

Multiregional Team. We posit that a multiregional team will be better at creating exceptional high technology than a regional team (the reference category). A multiregional team has physical distance separating its members, which alters the nature of the communication and ideation processes. As such, this geographic dispersion naturally buffers the two aforementioned creativity blockers (social inhibition and cognitive interference). In addition, nonlocal perspectives will infuse the creation team with differential knowledge (Lahiri 2010) and thereby foster divergent thinking among the collaborators (Franke, Poetz, and Schreier 2014). With less inhibition and interference and more diverse knowledge stores, a multiregional team will generate more and higher-quality ideas than if that team were engaged in ideation within a single region. Again, better ideas have more potential for market success. Therefore,

> H_{1b}: A country's proportion of multiregional teams is positively related to that country's high-technology exports.

Organizational Capital (Vehicle of Commercialization)

The innovation team (human capital) creates the high technology, and firm involvement (organization capital) provides a way for the high technology to be deployed into foreign markets. When associated with a firm, an innovation team has better access to organizational networks, including marketers, sales teams, engineers, and scientists (Singh and Fleming 2010). Firms are equipped with dynamic combinative capabilities to absorb new high technologies (Cohen and Levinthal 1990): they have the capabilities to assess the applicability of the high technology, integrate tacit-knowledge stores with product-development resources, and develop export relationships to prepare the high technology for market deployment. As such, firms represent a vehicle of commercialization for innovation and may influence high-technology export performance. In the context of internationalizing innovation, we define organizational capital as the degree of firm involvement during the creation of the high technology, and we assess the strength of the relational ties with the innovation team according to the assignment of ownership rights for the high technology. We classify firm involvement as follows:

- FIRM = 0 for a patent that has no firm involvement;
- FIRM = 1 for a patent with property rights assigned to a single firm (reference category); and
- FIRM = 2+ for a patent with property rights assigned to multiple firms.

Firm involvement is a function of the number of firms with intellectual property rights to the patented technology. A country has a portfolio of patents within its annual IIP, portions of which can belong to each of the three firm-involvement classifications. Approximately 85% of internationalizing patents in the sample have single-firm ownership; therefore, we deduce that single-firm involvement (FIRM = 1) represents the default resource manifestation: one invention, one firm. We will develop hypotheses about firm involvement that vary from this norm: no firm involvement (FIRM = 0) and multiple firm involvement (Firm = 2+).

No Firm (FIRM = 0). Because firms have established capabilities to deploy innovation resources, we posit that an innovation created without firm involvement is less likely to have market success than an innovation created with the involvement of one firm (the reference category). High technology is characterized by a fast-paced, short-product-life-cycle environment wherein potential inefficiencies have a deleterious effect on performance. Inherently, the resources and capabilities of the firm have the potential to provide efficiency gains when there is firm involvement (Coase 1937). The lack of access to these support mechanisms when patents have no firm involvement will result in a reduction of the timely potential for deployment of high technology to external markets. Therefore,

> H_{2a}: Patenting activity without firm involvement is negatively related to a country's high-technology exports.

Multiple Firms (FIRM = 2+). Although multiple firm involvement may increase the assets and resources that can be leveraged for innovation, we posit that multiple firm involvement limits the firms' ability to deploy resources due to coordination complexity (Jean, Sinkovics, and Kim 2010), potential opportunism (Seggie, Griffith, and Jap 2013; Wathne and Heide 2000), and agency conflicts (Gulati and Singh 1998). Thus, an innovation created with multiple firm involvement is less likely to have market success than an innovation created with the involvement of one firm (the reference category). The self-interest of each involved firm will inhibit the flow of knowledge across organizations and may result in learning races (Khanna, Gulati, and Nohria 1998). Concerns regarding hidden information and hidden actions (Bergen, Dutta, and Walker 1992), transaction costs (Williamson 1981), and monitoring (Kim and Mahoney 2005) will exacerbate the risk and complexity that is already present in attempts to internationalize innovation. Therefore,

> H_{2b}: Patenting activity with multiple firm involvement is negatively related to a country's high-technology exports.

Lone Genius

Lone genius is the intersection of a dimension of human capital (the sole inventor) and a dimension of organizational capital (no firm involvement). We contend that creation is a necessary condition for initializing the innovation-commercialization process, but firm involvement during this creation stage is not necessary. For the lone genius who creates high technology that can disrupt markets, we posit that commercialization avenues will present themselves. The lone genius, as the agent creator, will drive the innovation into new markets, whereas a firm places the innovation in existing channels and avenues of commercialization. Firms are limited by incumbent strategies that may influence perceived incentives, organizational filters, and organizational routines (Hannan and Freeman 1984). Whereas a lone genius has an ever-optimistic (perhaps even naive) perception of potential economic rents, an organization or team has an ever-conflictive perception of potential economic rents, because change may require cannibalizing current products, customers, and revenues. Furthermore, whereas a lone genius selects opportunities to exploit according to personal motivation, an organization or team filters opportunities to maximize the exploitation of existing resources and services. Finally, whereas a lone genius creates new routines, an organization or team develops routines "geared toward efficiently developing incremental innovations based on the current technology" (Chandy and Tellis 2000, p. 3).

In summary, the freedom associated with the lack of organizational bureaucracy allows the lone genius to undertake a creation process that is better than creation processes tied to organizational constraints. Schumpeter's lone genius (Schumpeter 1934, 1942), therefore, may trigger a chaotic disruption known as the butterfly effect (Straub 2013): "a small event in a remote part of the world [that] could trigger a chain of events that would add up to a disruptive change in the larger system." We posit that these forceful individuals can indeed disrupt markets through the introduction of novel technology without the direct involvement of a firm. Therefore,

> H_3: A country's proportion of lone geniuses is positively related to the country's high-technology exports.

Physical Capital (Technological Potential for Deployment)

Physical capital is the intellectual property embedded in high technology. Patents have the potential to represent valuable resources that may enable innovators to drive markets (Kumar, Scheer, and Kotler 2000). As such, these technologies may be valuable, rare, inimitable, and nonsubstitutable (Barney 1991), which provides a market position that is uncertain and immobile for outsiders (Foss and Knudsen 2003). Therefore, we posit that these patent characteristics may influence a country's high-technology export performance. We study two ex ante indicators of a patent's potential influence on market success (Novelli 2015; Sood and Tellis 2005): the patent's depth (patent scope as the amount of intellectual property) and its breadth (patent space as the applicability of said property). Because we have developed novel methods to extract additional information from patent documents, our approach provides a more exact distinction than has been drawn by much of the patent literature (Benner and Waldfogel 2008; Lanjouw and Schankerman 1997; Lerner 1994).

Depth. We define the patent depth aggregated within an IIP as the average number of independent claims per patent. The depth of a patent indicates the novelty of the invention and ultimately defines the scope of the high technology. Although a patent may have a large number of claims in general, it will likely have only a few independent claims: specifications of the invention's description without any dependencies on other claims within the patent (see 35 U.S.C. § 112). Based on this designation, independent claims capture the scope of novelty within a patent beyond existing patents, thereby representing new knowledge. A patent with more independent claims has more claimed intellectual property, which means that the patent has a stronger monopolistic position, and this increases its potential for successful commercialization and deployment. Therefore,

> H_{4a}: A country's average patent depth is positively related to that country's high-technology exports.

Breadth. We define the patent breadth aggregated within an IIP as the average number of unique technological classifications specified in a patent (Lerner 1994). Patent technology classifications represent the subject matter of a patent and can be considered the technological space within which the patent resides (Benner and Waldfogel 2008). If a patent belongs to a single technology classification, we conclude that it has a more focused applicability. In contrast, if a patent belongs to many technology classifications, we conclude that it has more conceivable applications. This raises several questions: If a firm has limited resources for deployment, how should those resources be allocated if more than one application is considered feasible? Should the firm commit to one application? If so, which one? Should the firm commit to all applications? What if the firm has experience commercializing one application but not the others? These questions represent potential intrafirm-agency conflicts that may result in a lack of commitment to the exporting process for a given application, thereby reducing the perceived positional advantage (Navarro et al. 2010) and actual market success. Therefore,

> H_{4b}: A country's average patent breadth is negatively related to that country's high-technology exports.

Leverage Interactions

Will the preceding hypotheses regarding depth and breadth also apply to the lone genius? We define the configuration of all three types of resources—a dimension of human capital (the sole inventor), a dimension of organizational capital (no firm involvement), and physical capital—as the leverage interactions of the lone genius. The lone genius faces significant risks when planning to innovate internationally. For the innovation to be developed into a product, the lone genius must have the ability to explain the technology and its application to interested parties, including investors, R&D teams, commercialization teams, and marketing managers. Because the lone genius has embedded codified knowledge, it is imperative for commercialization success that the market potential of the innovation can be both clearly described and easily explained. Specifically, this means that patents that have a narrow breadth and shallow depth are simpler for the lone genius to integrate into high-technology products for foreign markets. A patent with a single idea (i.e., one independent claim) and a single application (i.e., one technological classification) will be easier for a lone genius to commercialize than a patent with multiple ideas and multiple technological applications. For the lone genius, simplicity is imperative to offset the additional internationalizing-innovation risks. Therefore,

> H_5: Patent (a) depth and (b) breadth negatively moderate the relationship between the lone genius and a country's high-technology exports.

DATA AND MEASURES

We collected information on all U.S. patents between 1990 and 2010 as part of the Commercialization Research on Innovation and Entrepreneurship initiative.[1] We extracted necessary country-level patent information from this collection. We combine these patent data with data from multiple sources (United Nations 2014; World Bank 2015; World Trade Organization 2015) to construct a cross-sectional, longitudinal data panel. We used all available country-year observations such that these additional sources have the necessary data for the year in question. For example, Russia did not report economic data to the United Nations until 1996, so we have an unbalanced panel (a set of data in which country data are not available for certain years). We examine countries that have enough patents over time for panel-data analysis. For interactions, we compute the interaction at the patent level and then aggregate the results as part of this average profile. For robustness, we experimented with different sampling rules, and the nature of the results is consistent across the different rules. Our final sample consists of 50 countries.[2] In Table 1, we report correlations and summary statistics for the dependent variable and the main-effects predictors.

High-Technology Exports (EXPORTS)

Our dependent variable comes from the World Bank, an international organization that fosters economic development. One trade indicator in its data collection is

Table 1. Descriptive Statistics and Correlation Analysis

	M	SD	1	2	3	4	5	6	7	8	9
1. ln(high-technology exports)	22.03	2.22	1								
2. Human development (HDI)	.78	.10	.36***	1							
3. Trade openness (OPEN)	81.25	60.73	.22***	.21***	1						
4. WTO	.82	.39	.11**	.18***	.14***	1					
5. TEAM = sole inventor	.37	.16	–.05	.04	–.22***	–.30***	1				
6. TEAM = multiregional	.38	.19	–.31***	–.32***	.11***	.25***	–.72***	1			
7. FIRM = 0	.17	.14	–.46***	–.33***	–.23***	–.20***	.35***	–.04	1		
8. FIRM = 2+	.04	.05	–.03	–.10**	–.02	.09**	–.19***	.20***	–.03	1	
9. Independent claims (DEPTH)	2.43	.54	.00	.04	.06†	.32***	–.38***	.35***	–.14***	.03	1
10. Unique technologies (BREADTH)	1.64	.19	.00	–.03	–.05†	–.20***	–.20***	.10**	–.05	.00	.14***

†$p < .10$.
*$p < .05$.
**$p < .01$.
***$p < .001$.
Notes: Pearson pairwise correlations are reported. Correlations and summary statistics do not account for country-level and time-varying effects. We caution the reader about making inferences from these basic associations; they do not capture joint associations inherent to a regression model.

high-technology exports, sourced from the United Nations Comtrade database: "High-technology exports are products with high R&D intensity, such as in aerospace, computers, pharmaceuticals, scientific instruments, and electrical machinery. Data are in current U.S. dollars" (World Bank 2015 indicator TX.VAL.TECH.CD). For determining high-technology exports, we used the method developed by the Organisation for Economic Co-operation and Development (OECD). The method takes a product approach, derived from Hatzichronoglou (1997), rather than a sectoral approach: detailed industry codes (SITC Rev3) for nine categories of high-technology products (aerospace, computers–office machines, electronics–telecommunications, pharmacy, scientific instruments, electrical machinery, chemistry, nonelectrical machinery, and armament) are reported with the metadata.

Control Variables

As mentioned previously, we posit that exports in general and high-technology exports in particular require two conditions: basic human development and trade fluidity.

Human Development Index (HDI). We used the United Nations Human Development Index (HDI) to measure a country's basic human development in a given year. Specifically, the HDI "is a summary measure of average achievement in key dimensions of human development: a long and healthy life, being knowledgeable and having a decent standard of living. The HDI is the geometric mean of normalized indices for each of the three dimensions. The HDI was created to emphasize that people and their capabilities should be the ultimate criteria for assessing the development of a country, not economic growth alone" (United Nations 2014). The HDI is operationalized on a scale from 0 (low) to 100 (high). The United Nations reported the HDI in 1990, 2000, 2005, 2008, and 2010. To create a country-year observation from these trends, we performed a simple linear interpolation. We intentionally selected this measure because it is *not* a financial measure, thus reducing concerns of endogeneity with the dependent variable.

Trade Openness (OPEN). We used two measures to capture a country's trade fluidity. The first measure represents a country's ability to import and export goods and services. We use this measure to define trade openness (OPEN) and operationalize it in the traditional way (Gries and Redlin 2012), by summing a country's imports and exports (as a percentage of its gross domestic product; respectively, World Bank 2015 indicators NE.IMP.GNFS.ZS and NE.EXP.GNFS.ZS).

World Trade Organization (WTO). The second measure of trade fluidity indicates whether or not the World Trade Organization (WTO) existed in a given year. The WTO "is the only global international organization dealing with the rules of trade between nations. At its heart are the WTO agreements, negotiated and signed by the bulk of the world's trading nations and ratified in their parliaments. The goal is to help producers of goods and services, exporters, and importers conduct their business" (World Trade Organization 2015). In short, the WTO encourages an open global economy.

Internationalizing-Innovation Experience (IIE)

We operationalize IIE as a tercile split of country-level patenting activity for all internationalizing innovation in a given year. We assign a country-year profile to one of three subsamples according to its tercile membership: the lower tercile (LOW) represents the nascent phase of IIE ($\lesssim$50 patents a year), the upper tercile (HIGH) represents the mature phase of IIE ($\gtrsim$450 patents a year), and the middle tercile (MID) represents the adolescent phase of IIE.

Internationalizing-Innovation Profile (IIP)

Innovation Team (TEAM = Sole Inventor, Regional Team, Multiregional Team). We extracted inventors and inventor locations from each U.S. patent provided by the U.S. Patent and Trademark Office between 1990 and 2010. We used Google Maps' application program interface (API) service to uniquely identify each inventor's longitude and latitude at the time when the patent was granted. From this information, we ascertained the nature of an innovation team as belonging to one of three classifications: sole inventor, regional team, or multiregional team. For patents with more than one inventor, we assign inventors to regions on the basis of a distance rule. For each inventor beyond the first one, we compute pairwise distances with all previous inventors (who are already assigned to a region). If the new inventor is within 50 miles of an inventor in any previously assigned region, that inventor is added to that region; otherwise, a new region is created. Within a country's IIP, we aggregate the proportions of patents belonging to each class. We choose the regional team as the reference class.

Firm Involvement (FIRM = 0, 1, 2+). We also extracted information about firm involvement for each patent: no firm, one firm, or multiple firms. Within a country's IIP, we aggregate the proportions of patents belonging to each of these classes. We choose one firm (*FIRM = 1*) as the reference class.

Patent Depth (DEPTH). We developed a custom algorithm to ascertain whether a claim on a patent is independent or dependent. In general, an independent claim begins with language such as "A method for ...," and a dependent claim begins with language such as "The method of claim *N* wherein ...," where N is a reference to a claim number previously described in the patent. For each patent, we count the number of independent claims, and we operationalize depth as the average number of independent claims per patent within a country's IIP.

Patent Breadth (BREADTH). The U.S. Patent Classification System (USPC) is "a system for organizing all U.S. patent documents and many other technical documents into relatively small collections based on common subject matter. Each subject matter division in the USPC includes a major component called a class" (United States Patent Office 2012). For each patent, we count the number of unique USPC classes, and we operationalize breadth as the average number of such unique technology classifications per patent within a country's IIP.

Lone Genius. We define a patent that has one inventor (TEAM = sole inventor) and no firm involvement (FIRM = 0) as a lone-genius patent. Within a country's IIP, we aggregate this measure as the proportion of patents belonging to this designation.

Leverage. We additionally capture the patent depth and breadth of lone-genius patents. Following the recommendations of Aiken, West, and Reno (1991, p. 49) that first-order and second-order terms should be included, we also capture the patent depth and breadth for the lower-order terms: one inventor (TEAM = sole inventor) and no firm involvement (FIRM = 0).

MODEL DEVELOPMENT AND RESULTS

We define our linear model[3] in terms of Y_{jt}, the natural-log transformation of high-technology exports (in current US dollars):

$$Y_{jt} = \alpha + \boldsymbol{\beta} X_{jt} + \upsilon_j + \varepsilon_{jt}, \quad (1)$$

where α is the grand mean, υ_j is the fixed-time country mean, X_{jt} (country j at time t) is the matrix of country-level observations for the vector of parameters $\boldsymbol{\beta}$, and ε_{jt} represents the residual idiosyncratic disturbance. Our panel consists of repeated observations of countries over time. Therefore, we employ cross-section time-series models. This approach redefines Equation 1 by subtracting time-demeaned values. This *within* transformation subtracts constant country effects for the dependent variable $\overline{Y_j}$, the predictor variables $\overline{X_j}$, and the intercept $\overline{\upsilon_j}$:

$$\left(Y_{jt} - \theta\overline{Y_j}\right) = (1-\theta)\alpha + \boldsymbol{\beta}\left(X_{jt} - \overline{X_j}\right) + \left(\upsilon_{jt} - \theta\overline{\upsilon_j}\right). \quad (2)$$

If $\theta = 0$, the model reduces to a basic pooled ordinary least squares (OLS) model; if $\theta = 1$, the model reduces to a fixed-effects model; otherwise, the model represents a random-effects model. The pooled OLS estimation is biased if country effects exist (Hsiao 2003). The random-effects model may be susceptible to omitted-variable bias (Wooldridge 2006), bias that arises because a predictor was excluded from the model specification. In contrast, the fixed-effects model is not susceptible to this bias because it captures unobserved intracountry variation around its average country-level "fixed effect." Panel-data analysis commonly has issues with heteroskedasticity, serial autocorrelation, and cross-sectional autocorrelation.

We emphasize that such issues do not bias the estimates. The variance of the estimates (i.e., the standard errors) may, however, be biased, which would invalidate the interpretation of an estimate's significance. We can account for potential variance bias using robust standard errors, adjustments to the standard errors that can control for the issue(s) at hand. The Driscoll and Kraay (1998) robust standard errors can be used to address heteroskedasticity and simultaneously both serial autocorrelation and cross-sectional autocorrelation. Using these adjusted standard errors, we report quasi t-tests to determine the significance of a parameter estimate. We perform our analysis using the plm package and vcovSCC robust errors within the R statistical programming language (Croissant and Millo 2008).

Estimation Results

We report results for 12 models using fixed country effects: 3 parameter specifications (M1: main effects, M2: lone genius, M3: leverage interactions) × 4 samples. We report estimation results for the four samples—total, nascent phase IIE, adolescent phase IIE, and mature phase IIE—in Tables 2, 3, 4, and 5, respectively. For brevity, we report the following robustness checks for the main effects, total sample specification (we performed all necessary robustness checks across all sample-parameter specifications). When we compared the pooled OLS (adjusted $R^2 = .387$) with the fixed-effects model

Table 2. Estimates of Independent Variables on Export Performance Using Fixed Country Effects: Total Sample

Description	Variable	Dependent Variable: ln(High-Technology Exports) Model 1	Model 2	Model 3
HDI	β_1	14.43 (1.19)***	14.37 (1.24)***	14.66 (1.29)***
OPEN	β_2	.01 (.00)***	.01 (.00)***	.01 (.00)***
WTO	β_3	.25 (.05)***	.25 (.05)***	.25 (.05)***
TEAM = sole inventor	β_4	.80 (.27)**	.55 (.25)*	.01 (.50)
TEAM = multiregional	β_5	.63 (.21)**	.57 (.20)**	.55 (.21)**
FIRM = 0	β_6	–21 (.27)	–.78 (.18)***	.24 (.58)
FIRM = 2+	β_7	–.28 (.28)	–.39 (.23)†	–.42 (.27)
DEPTH	β_8	.03 (.05)	.03 (.05)	.03 (.07)
BREADTH	β_9	.05 (.09)	.04 (.09)	.11 (.07)
LONE GENIUS	β_{10}		.97 (.41)*	1.52 (1.05)
DEPTH × LONE GENIUS	β_{11}			–.76 (.69)
DEPTH × (TEAM = sole inventor)	β_{12}			.53 (.33)
DEPTH × (FIRM = 0)	β_{13}			–.60 (.36)†
BREADTH × LONE GENIUS	β_{14}			.17 (.15)
BREADTH × (TEAM = sole inventor)	β_{15}			–.07 (.10)
BREADTH × (FIRM = 0)	β_{16}			.00 (.10)
	N	943	943	943
	Number of countries	50	50	50
	R^2	.7085	.7111	.7165
	Adjusted R^2	.6642	.6658	.6664
	Model fit F-statistic	$F_{9, 884} = 238.76$, $p < .001$	$F_{10, 883} = 217.31$, $p < .001$	$F_{16, 877} = 138.56$, $p < .001$

†$p < .10$.
*$p < .05$.
**$p < .01$.
***$p < .001$.
Notes: Sample is the total of all observations for panel of 50 countries from 1990 through 2010. Fixed-effect models do not have an intercept term. Data represent values of $\hat{\beta}$; in parentheses, we report the Driscoll and Kraay (1998) robust standard errors, from which we derive quasi t-tests to ascertain the significance of each parameter estimate.

Table 3. Estimates of Independent Variables on Export Performance Using Fixed Country Effects: Nascent Phase IIE

Description	Variable	Dependent Variable: ln(High-Technology Exports) Model 1	Model 2	Model 3
HDI	β_1	17.89 (1.92)***	17.88 (2.07)***	17.98 (2.18)***
OPEN	β_2	.02 (.00)***	.02 (.00)***	.02 (.00)***
WTO	β_3	.36 (.11)**	.34 (.12)**	.33 (.12)**
TEAM = sole inventor	β_4	.01 (.23)	–.31 (.21)	–.27 (.44)
TEAM = multiregional	β_5	.08 (.13)	–.02 (.13)	–.05 (.18)
FIRM = 0	β_6	.24 (.22)	–.42 (.17)*	.46 (.74)
FIRM = 2+	β_7	–.17 (.35)	–.30 (.30)	–.35 (.34)
DEPTH	β_8	.04 (.06)	.05 (.06)	.03 (.08)
BREADTH	β_9	.09 (.07)	.08 (.07)	.23 (.09)*
LONE GENIUS	β_{10}		1.12 (.41)**	1.10 (1.27)
DEPTH × LONE GENIUS	β_{11}			–.18 (.82)
DEPTH × (TEAM = sole inventor)	β_{12}			–.04 (.28)
DEPTH × (FIRM = 0)	β_{13}			–.55 (.38)
BREADTH × LONE GENIUS	β_{14}			.08 (.12)
BREADTH × (TEAM = sole inventor)	β_{15}			.04 (.11)
BREADTH × (FIRM = 0)	β_{16}			.00 (.11)
	N	317	317	317
	Number of countries	27	27	27
	R^2	.6843	.6911	.6963
	Adjusted R^2	.6066	.6105	.6019
	Model fit F-statistic	$F_{9, 281} = 67.69$, $p < .001$	$F_{10, 280} = 62.65$, $p < .001$	$F_{16, 274} = 39.27$, $p < .001$

†$p < .10$.
*$p < .05$.
**$p < .01$.
***$p < .001$.
Notes: Sample is the LOW subsample (nascent phase of IIE, defined as low level of patenting). Fixed-effect models do not have an intercept term. Data represent values of $\hat{\beta}$; in parentheses, we report the Driscoll and Kraay (1998) robust standard errors, from which we derive quasi t-tests to ascertain the significance of each parameter estimate.

Table 4. Estimates of Independent Variables on Export Performance Using Fixed Country Effects: Adolescent Phase IIE

		Dependent Variable: ln(High-Technology Exports)		
Description	Variable	Model 1	Model 2	Model 3
HDI	β_1	12.61 (1.38)***	12.65 (1.38)***	11.61 (1.46)***
OPEN	β_2	.01 (.00)***	.01 (.00)***	.01 (.00)***
WTO	β_3	.37 (.11)**	.37 (.11)**	.38 (.11)***
TEAM = sole inventor	β_4	2.90 (.49)***	3.05 (.59)***	1.49 (1.37)
TEAM = multiregional	β_5	1.85 (.38)***	1.89 (.41)***	1.82 (.42)***
FIRM = 0	β_6	–.95 (.40)*	–.58 (.81)	–1.87 (1.14)
FIRM = 2+	β_7	–1.17 (.56)*	–1.05 (.58)†	–1.23 (.62)*
DEPTH	β_8	.23 (.07)**	.22 (.07)**	.29 (.08)***
BREADTH	β_9	–.46 (.16)**	–.45 (.15)**	–.71 (.23)**
LONE GENIUS	β_{10}		–.62 (.95)	3.77 (2.11)†
DEPTH × LONE GENIUS	β_{11}			–3.27 (1.13)**
DEPTH × (TEAM = sole inventor)	β_{12}			.86 (.59)
DEPTH × (FIRM = 0)	β_{13}			1.56 (.52)**
BREADTH × LONE GENIUS	β_{14}			.45 (.51)
BREADTH × (TEAM = sole inventor)	β_{15}			.08 (.22)
BREADTH × (FIRM = 0)	β_{16}			–.78 (.30)**
	N	305	305	305
	Number of countries	25	25	25
	R^2	.7851	.7854	.7943
	Adjusted R^2	.6976	.6953	.6876
	Model fit F-statistic	$F_{9, 271} = 110.01$, $p < .001$	$F_{10, 270} = 98.8$, $p < .001$	$F_{16, 264} = 63.73$, $p < .001$

†$p < .10$.
*$p < .05$.
**$p < .01$.
***$p < .001$.
Notes: Sample is the MID subsample (adolescent phase of IIE, defined as middle level of patenting). Fixed-effect models do not have an intercept term. Data represent values of $\widehat{\beta}$; in parentheses, we report the Driscoll and Kraay (1998) robust standard errors, from which we derive quasi t-tests to ascertain the significance of each parameter estimate.

Table 5. Estimates of Independent Variables on Export Performance Using Fixed Country Effects: Mature Phase IIE

Description	Variable	Dependent Variable: ln(High-Technology Exports)		
		Model 1	Model 2	Model 3
HDI	β_1	5.73 (.97)***	5.70 (.90)***	5.65 (.72)***
OPEN	β_2	.01 (.00)***	.01 (.00)***	.01 (.00)***
WTO	β_3	.15 (.03)***	.16 (.04)***	.18 (.03)***
TEAM = sole inventor	β_4	–.81 (.35)*	–.82 (.34)*	.93 (.91)
TEAM = multiregional	β_5	.01 (.42)	.02 (.41)	–.25 (.52)
FIRM = 0	β_6	–1.34 (.31)***	–1.62 (2.05)	.04 (3.07)
FIRM = 2+	β_7	2.83 (.96)**	2.83 (.96)**	2.91 (.93)**
DEPTH	β_8	–.05 (.07)	–.05 (.07)	.18 (.08)*
BREADTH	β_9	.07 (.29)	.07 (.28)	.37 (.34)
LONE GENIUS	β_{10}		.36 (2.39)	.50 (2.88)
DEPTH × LONE GENIUS	β_{11}			–3.23 (2.63)
DEPTH × (TEAM = sole inventor)	β_{12}			–.43 (.65)
DEPTH × (FIRM = 0)	β_{13}			2.24 (2.60)
BREADTH × LONE GENIUS	β_{14}			2.65 (1.80)
BREADTH × (TEAM = sole inventor)	β_{15}			–.56 (.27)*
BREADTH × (FIRM = 0)	β_{16}			–2.76 (.97)**
	N	321	321	321
	Number of countries	19	19	19
	R^2	.8266	.8266	.8331
	Adjusted R^2	.7545	.752	.7422
	Model fit F-statistic	$F_{9, 293} = 155.21, p < .001$	$F_{10, 292} = 139.23, p < .001$	$F_{16, 286} = 89.2, p < .001$

†$p < .10$.
*$p < .05$.
**$p < .01$.
***$p < .001$.
Notes: Sample is the HIGH subsample (mature phase of IIE, defined as high level of patenting). Fixed-effect models do not have an intercept term. Data represent values of $\hat{\beta}$; in parentheses, we report the Driscoll and Kraay (1998) robust standard errors, from which we derive quasi t-tests to ascertain the significance of each parameter estimate.

(adjusted $R^2 = .664$), we determined that country-level effects were indeed present ($F_{49,884} = 298.19$, $p < .001$).

We diagnosed potential multicollinearity problems: high correlations among predictor variables may lead to unreliable and unstable estimates of the regression coefficients. From the data in Table 1, we observed that TEAM = multiregional strongly correlates with TEAM = sole inventor in the negative direction. Within the pooled OLS, we first performed the stepwise approach of including one variable at a time and heuristically observing the consistency of the parameter estimates. Next, we calculated variance inflation factors and noted that the two aforementioned TEAM classifications have the highest variance inflation factors (sole inventor = 2.96; multiregional = 2.79). From these diagnostics, we concluded that multicollinearity is not a problem with our model specification. Inefficiencies may arise from including interaction terms in the model, but the parameter estimates will still be consistent and unbiased (Wooldridge 2006, chap. 3).

In addition, we performed the augmented Dickey–Fuller test for one lag (DF = –6.0653, $p < .01$) and two lags (DF = –6.3208, $p < .001$) and concluded that no unit roots (e.g., trends) were present in our data. Next, we performed the Breusch–Pagan test ($BP_9 = 99.5$, $p < .001$) and ascertained the presence of heteroskedasticity. We then performed both the Durbin–Watson test (DW = .5133, $p < .001$) and the Breusch–Godfrey–Wooldridge test ($\chi^2_6 = 534.09$, $p < .001$) and concluded that serial autocorrelation was present. We performed the Breusch–Pagan Lagrange multiplier test ($\chi^2_{1225} = 5{,}450.4$, $p < .001$) and concluded that cross-sectional autocorrelation was also present in our panel. Finally, when we compared the random-effects model (adjusted $R^2 = .670$) with the fixed-effects model (adjusted $R^2 = .664$), we determined that the fixed-effects specification was more reliable using the Hausman test ($\chi^2_9 = 928.22$, $p < .001$).

Findings

In this section, we review the regression results to summarize our findings. First, we examined each model for significance and concluded that the hypothesized models fit well with the data. Second, we concluded that the fixed country effects represent consistent and unbiased parameter estimates. Third, with the use of the Driscoll and Kraay (1998) robust standard errors, we adjusted any variance bias to ascertain the significance of these consistent estimates. Therefore, we can make inferences about the hypotheses using our model estimates. For ease of interpretation across these 12 models, we introduce ${}^{M1}_{Total}\widehat{\beta}_1$ as notation to refer to parameter estimate $\widehat{\beta}_1$ (HDI) for Model 1: main effects (M1) and the total sample (Total). We will proceed by reporting findings for the total sample. The impact of innovation teams on high-technology exports is verified: a higher proportion of sole inventors in a country's IIP positively (${}^{M1}_{Total}\widehat{\beta}_4 = .80$, $p < .01$) influences high-technology exports (H_{1a}), and a higher proportion of multiregional teams in a country's IIP positively (${}^{M1}_{Total}\widehat{\beta}_5 = .63$, $p < .01$) influences high-technology exports (H_{1b}). The impact of firm involvement on high-technology exports could not be statistically verified with the total sample: there was no evidence that a higher proportion of no firm involvement in a country's IIP negatively (${}^{M1}_{Total}\widehat{\beta}_6 = -.21$, n.s.) influences high-technology exports (H_{2a}), nor was there evidence that a higher proportion of multifirm involvement in a country's IIP negatively (${}^{M1}_{Total}\widehat{\beta}_7 = -.28$, n.s.) influences high-technology exports (H_{2b}). We do corroborate the lone-genius hypothesis: a higher proportion of lone geniuses in a country's IIP positively (${}^{M2}_{Total}\widehat{\beta}_{10} = .97$, $p < .05$) influences high-technology exports (H_3). We do not find evidence to support the hypotheses linking patent depth (${}^{M1}_{Total}\widehat{\beta}_8 = .03$, n.s.) and breadth (${}^{M1}_{Total}\widehat{\beta}_9 = .05$, n.s.) with high-technology exports ($H_{4a–b}$). Similarly, we do not find any evidence of the leverage interactions for depth (${}^{M3}_{Total}\widehat{\beta}_{11} = -.76$, n.s.) and breadth (${}^{M3}_{Total}\widehat{\beta}_{14} = .17$, n.s.) and the lone genius influencing high-technology exports ($H_{5a–b}$).

As an avenue for exploration, we additionally proposed that the IIE phase would influence these relationships. As post-hoc analyses, in Table 6, we compare the hypothesized findings for the total sample with each subsample. For the nascent phase of IIE (low patenting activity), we observe that only the lone genius matters (${}^{M2}_{LOW}\widehat{\beta}_{10} = .97$, $p < .05$). For the adolescent phase of IIE (middle patenting activity), we observe that almost everything matters, with the exception of the lone genius and the leverage interaction of the lone genius with breadth. However, when we consider the complexities and contingencies of the interaction model, there is some evidence that the lone genius matters (${}^{M3}_{MID}\widehat{\beta}_{10} = 3.77$, $p < .10$). For the mature phase of IIE (high patenting activity), direct evidence supports a negative relationship with a sole inventor (${}^{M1}_{HIGH}\widehat{\beta}_4 = -.81$, $p < .05$) and no firm involvement (${}^{M1}_{HIGH}\widehat{\beta}_6 = -1.34$, $p < .001$) and a positive relationship with multiple firm involvement (${}^{M1}_{HIGH}\widehat{\beta}_7 = 2.91$, $p < .01$). The relationships in the mature phase of IIE are opposite to the hypothesized direction for the sole inventor (${}^{M1}_{MID}\widehat{\beta}_4 = 2.90$, $p < .001$) and multiple firm involvement (${}^{M1}_{MID}\widehat{\beta}_7 = -1.17$, $p < .01$). These findings are also

Table 6. Summary of Hypotheses and Results

Hypothesis	Relationship	Variable	Total	Low	Mid	High
H_{1a}	+	TEAM = sole inventor (β_4)	✓		✓	×
H_{1b}	+	TEAM = multiregional (β_5)	✓		✓	
H_{2a}	–	FIRM = 0 (β_6)			✓	✓
H_{2b}	–	FIRM = 2+ (β_7)			✓	×
H_3	+	LONE GENIUS (β_{10})	✓	✓		
H_{4a}	+	DEPTH (β_8)			✓	
H_{4b}	–	BREADTH (β_9)			✓	
H_{5a}	–	DEPTH × LONE GENIUS (β_{11})			✓	
H_{5b}	–	BREADTH × LONE GENIUS (β_{14})				

Notes: ✓ = hypothesis supported; × = hypothesis refuted. A hypothesis is supported/refuted if the variable under examination is significant for the appropriate model. Model 1 is used to test main effects for $H_{1a–b}$, $H_{2a–b}$, and $H_{4a–b}$; Model 2 is used to test lone genius for H_3; Model 3 is used to test leverage interactions for $H_{5a–b}$.

opposite to the relationships in the adolescent phase of IIE. At some point in the IIE development of a country, there is a change that reverses these relationships with high technology. Such a change supports our S-curve conceptual model. When a country's IIE develops, at some point in time, the inertia of existing opportunities and the incumbent capacities of existing export activities change how IIPs influence high-technology exports.

We conclude this section by reporting on the control variables. Overall, we observed, as expected, positive relationships between these factors and high-technology exports. This supports our proposition that human development (${}^{M1}_{Total}\widehat{\beta}_1 = 14.43$, $p < .001$) and trade fluidity defined by both openness (${}^{M1}_{Total}\widehat{\beta}_2 = .01$, $p < .001$) and the creation of the WTO (${}^{M1}_{Total}\widehat{\beta}_3 = .25$, $p < .001$) indeed represent necessary conditions for innovation. Because we compare these results across levels of IIE, we note that these necessary conditions are even more influential during the nascent phase of IIE (${}^{M1}_{LOW}\widehat{\beta}_1 = 17.89$, $p < .001$; ${}^{M1}_{LOW}\widehat{\beta}_2 = .02$, $p < .001$; ${}^{M1}_{LOW}\widehat{\beta}_3 = .36$, $p < .001$) than during the mature phase of IIE (${}^{M1}_{HIGH}\widehat{\beta}_1 = 5.73$, $p < .001$; ${}^{M1}_{HIGH}\widehat{\beta}_2 = .01$, $p < .001$; ${}^{M1}_{HIGH}\widehat{\beta}_3 = .15$, $p < .001$).

DISCUSSION

Our study of 50 countries from 1990 through 2010 highlights that a resource-based framework can be applied at the country level in order to link innovation and high-technology exports. We find that human capital, organizational capital, and physical capital all affect export performance. By carefully defining the lone genius according to its component deconstructions (the sole inventor and no firm involvement), we gain a more nuanced perspective of how IIE influences the impact of these resource configurations on market success. This research has important implications for both theory and practice.

Theoretical Implications

The primary theoretical implication from our research is the support for Schumpeter's lone-genius hypothesis. A precise construction of the interactions of human capital, organizational capital, and physical capital enables us to carefully test this hypothesis. For the creation of internationalizing innovation, the findings indicate that lone genius can contribute to the economic outputs of a country. Therefore, Schumpeter's theory of economic development (Schumpeter 1934) should not be discarded as irrelevant. In fact, we have demonstrated that the "creative destructions" of lone geniuses support a country's export performance. Indeed, impactful innovation can originate outside of a firm (or team), and forceful individuals armed with patented technology can deploy resources to new economic shores. Resource theories that require organizational capital in the commercialization of the innovation should not require such capital during the creation of the innovation. Our research extends the international marketing literature on export performance, specifically when considering high-technology innovations, by demonstrating that the resource perspective can be applied to external agents. As such, at the firm level, our findings contribute to the literature by emphasizing the importance of boundary-spanning capabilities: the firm as the commercialization vehicle may find agents of creation outside of its organizational control.

Resource perspectives within the international marketing literature related to exporting have mainly been used to investigate the capabilities and resources that are available within the firm (e.g., Lages, Silva, and Styles 2009). By developing a resource–experience–performance framework at the country level, we extend prior research that considers how firm-level resource configurations (e.g., Diamantopoulos et al. 2014; Hortinha, Lages, and Lages 2011; Theodosiou and Katsikea 2013) and market relationships (e.g., Griffith and Rubera 2014; Zeriti et al. 2014) influence exports. Our study contributes to the understanding of how innovation is developed and deployed within the country-level context: the resource–experience–performance framework we have developed links together human capital, organizational capital, and physical capital while also considering the experience that exists within the country. Extending the existing literature, the results of this study show that the specific combinations of these resources are of key importance for performance outcomes.

While we find that it is important to consider various resource contingencies, we also find that it is important to consider country-level experience in the internationalization of innovation. Our finding that innovation experience moderates a country's ability to deploy innovation resources into external markets also adds value to the literature. Whereas recent research has demonstrated the importance of considering the impact of resources and capabilities across countries (e.g., Eisend, Evanschitzky, and Calantone 2016), our findings highlight not just the existence of differences across countries but also the dynamic nature of these country-level resources and their potential for growth. We posit that this substantiates the theoretical claims regarding the "complexity of context" in international marketing (Akaka, Vargo, and Lusch 2013). We conclude that a diversity of resources together with a multiplicity of institutions at varying levels of experience ultimately determine the dynamic state of a country's innovative capacities. Given this, theory should embrace the subtleties of the dynamics of innovation ecosystems by simultaneously examining multilevel perspectives: innovation level, firm level, and country level.

Managerial and Public Policy Implications

Our results provide key insights for international marketing managers. First, marketing managers may need to focus on different configurations of the resources associated with innovation, depending on the phase of their development of IIE. Under circumstances that support the impact of lone genius, international marketing managers should seek out lone geniuses (agents of creation that thrive beyond the firm's boundaries). Marketing managers should provide an open-innovation platform (Chesbrough 2003); their collaboration efforts and talent programs should respect the intrinsic motivations and autonomy of the lone genius. If such efforts have been made to encourage and support the lone genius, then when a high technology is conceived, the firm will already have established a rapport and working relationship with the lone genius, placing the firm in a position to step in as the lone genius's vehicle for commercialization.

Beyond the lone genius, there are other factors of interest for international marketing managers. In countries that have advanced past the nascent phase of IIE, the management of innovation should focus on the various forms of capital that affect high-technology exports. In the adolescent phase of IIE, creativity needs to be nurtured within the firm, divergent thinking needs to be cultivated, and geographic diversity needs to be encouraged. In the mature phase, interfirm alliances and deployment can be considered and executed. Creativity and discovery will most likely occur within regional teams that are tied to a firm.

Country-level public policy should support the development of internationalizing innovation by recognizing the importance of firm-level involvement in the commercialization process but not necessarily in the creation process. While countries should promote exports (Leonidou, Palihawadana, and Theodosiou 2011), they also should consider ways to maximize innovation creation and overall economic development. Policy makers need to understand that the experience that exists within the country affects which factors influence high-technology exports. Furthermore, depending on the level of experience, different innovation characteristics can be promoted in order to support the creation of innovation.

For countries in the nascent phase of IIE, policies could be developed to promote the creation of innovation through programs (i.e., access to technology resources) that enable tinkering, that encourage creativity and discovery, and that facilitate the development of commercialization avenues for the lone genius. Rather than distracting the lone genius with noncreative, executive tasks (e.g., incorporating or developing a business plan), programs in this phase should seek out, encourage, and support creative knowledge workers in the hope that they will develop new technology that will ultimately benefit the country. In countries in the adolescent phase of IIE, the incumbent methods of innovation deployment are being established. Therefore, these countries should develop public policy that will directly influence performance yields: they should promote firm building (e.g., incubators and accelerators) and diverse thinking among sole inventors and multiregional teams within firms, and they should establish routines and procedures to deploy high technology into foreign markets. For countries in the mature phase of IIE, organizational control of the high technology is best, and alliances across firm boundaries will enhance export performance (Swaminathan and Moorman 2009; Zhang et al. 2010). Public policy initiatives should protect the firm's rights to the intellectual property and also encourage interfirm collaborations. In summary, public policy should encourage context-specific capability development with programs that facilitate innovation making (Hatch 2013), firm making, and alliance making in the nascent, adolescent, and mature phases of IIE, respectively.

LIMITATIONS AND FUTURE RESEARCH

This study has several limitations that present opportunities for future research. First, because of the statistical complexity of analyzing and controlling for multiple patent-granting nations, we studied the internationalizing innovation of these 50 countries into only one external market, the United States. This enabled measurement equivalency and generalizable inferences; however, future research could use multiple patent markets to clarify the specific actions that are taken within the context of the target market. This could contribute to an understanding of which and how many markets are targeted depending on the capital involved in the innovation process.

Second, we studied innovation performance at the country level, yet we know that countries often have innovation hot spots or regions. For example, the city of Shenzhen, China, has become known as the "Silicon Valley of hardware" (Sheehan 2014). The city itself has developed a unique environment that encourages collaboration among stakeholders in the innovation-export process: multinational corporations, high-technology firms, nearby suppliers, and local government support. By developing theory across levels (e.g., city, region, and country), research will be able to better explain the nuances related to both the geographic dispersion of innovation (e.g., team membership and firm involvement) and the interaction of innovation environments, according to the policies and institutions involved at the varying levels.

Third, we have proposed and verified that IIE matters by performing a tercile split of patenting activity. Future research could build upon this S-curve conceptualization by further investigating the progression across phases. Potential research could identify the mechanisms and motivations that lead to the progression and how such a progression interacts with a firm's marketing strategy. Whereas most marketing research on exports has focused on the firm, research on this progression would provide important information about the contextual development of the firm's environment. In addition, future research could explore IIE development within regions of the United States: does the lone genius matter in the United States in regions with nascent IIE development?

Fourth, whereas we have developed a general, cross-country methodology with IIP and IIE to study their impact on high-technology exports, future research could further explore the mechanisms of the process generally and of the lone-genius creations specifically. Why does the lone genius matter in the nascent phase but not the mature phase? How does the lone genius find avenues of commercialization? Is the lone genius "socially isolated" (Singh and Fleming 2010)? What are optimal institutionalizing policies that countries should develop to advance innovation and economic development?

Finally, studies could also try to understand the mechanisms within firms by which these measurement-equivalent resources and capabilities are activated and deployed into foreign markets. How exactly do marketing managers interact with innovation teams? How does the interaction of marketing and technological capabilities (Yalcinkaya, Calantone, and Griffith 2007) improve the creativity processes, encourage divergent thinking, and stimulate breakthrough discoveries? How can marketing managers better leverage the resources at their disposal to maximize returns on innovation?

NOTES

1. The aim of this initiative is to create better patent data to help academics do better research. See http://crie.org for more details.

2. We report the country list in Figure 1. Please contact the authors for additional country-specific data (proportions of lone genius by country, dynamics of IIPs, fixed effects, etc.).

3. Because high-tech exports represent a short product life cycle, we conducted a contemporaneous study on profiles and exports. In this context, we posit that IIPs in year t should coincide with high-tech exports in year t. A patent is included in a country's IIP in the year it is granted. Each

patent has been in an application review process for several years. The innovator has had time during this review process to prepare to take the innovation to the external market. There are possible residual, carry-over effects into future years, but in this fast-paced context, we posit that this approach is a conservative estimate of the relationship between IIPs and high-tech exports.

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