Humanities & Social Sciences Communications

ARTICLE

https://doi.org/10.1057/s41599-023-01890-w OPEN

The determinants of the use of process control mechanisms in FDI decisions in headquarters–subsidiary relationships

Chun-Chien Lin [1], Yu-Ching Chiao[2]✉, Tung-Lung Chang[3] & Yu-Chen Chang[2]

This study investigates the impact of foreign direct investment (FDI) motivations and technological resource commitment on headquarters' employment of process control over subsidiaries, to better understand the process control mechanisms. Drawing on agency theory and the resource dependence perspective, a cross-sectional data model is developed among the 1541 Taiwanese manufacturing firms engaged in foreign investments, 1015 headquarters–subsidiary (HQ–Sub) relationships in China were selected from the database; in each of these relationships, the headquarters is located in Taiwan, while the subsidiary is located in China. Our findings reveal that the headquarters will use process control if the primary motivation for setting up a subsidiary in a host country is resource-seeking, but not use process control with market-seeking motivation. This control process relationship is enhanced/weakened/weakened by the headquarters'/subsidiaries'/partners' technological resource commitment. Taiwanese multinational corporations (MNCs) from newly industrialized economies (NIEs) seeking to choose control mechanisms that fit their technological resources and FDI motivations in China are given guidelines. It adds to the use of control mechanisms with HQ-Sub literature. Both resource-seeking and market-seeking motivations shed light on technological resource commitment by various units of an MNC, to ward off information asymmetry.

[1] Department of Business Administration, National Chin-Yi University of Technology, Taichung, Taiwan, ROC. [2] Department of Business Administration, National Chung Hsing University, Taichung, Taiwan, ROC. [3] Marketing and International Business, Long Island University, Brookville, NY, USA.
✉email: chiaoy@dragon.nchu.edu.tw

Introduction

It has long been known that headquarters-subsidiary (HQ-Sub) relationships with respect to multinational corporations (MNCs) are varied and constantly evolving, depending on political connections (Li et al., 2017; Lu et al., 2018; Ma et al., 2021; Wang et al., 2019), entry mode (Albertoni et al., 2019; Amankwah-Amoah et al., 2022; Li et al., 2020, 2021; Schwens et al., 2018), motivation (Duanmu and Lawton, 2021; Elia et al., 2019), network (Lin, 2019; Mas-Ruiz et al., 2018; Moalla and Mayrhofer, 2020), and resource commitment (Agnihotri et al., 2022; Wan et al., 2023) as shown in Table 1.

For parent firms, establishing a productive HQ-Sub relationship poses a critical challenge (Wan et al., 2023), and such a relationship could have an impact on the MNC's control mechanisms (Agnihotri et al., 2022). In literature, two streams of research have explored the design of appropriate control mechanisms (Pugliese et al., 2014). The first, consistent with the "logic of agency" on resource-dependent theory (RDT), suggests that the design of control mechanisms follows a parent firm's global strategy with regard to particular objectives (i.e., licensing, R&D contracts, and direct/indirect exports) (Agnihotri et al., 2022; Albertoni et al., 2019; Amankwah-Amoah et al., 2022). However, previous studies tend to overlook the fact that MNCs' global strategies may be characterized by multiple rather than a single objective (Doz and Prahalad, 1984; Stendahl et al., 2021). The second, associated with the resource commitment perspective in recent decades, emphasizes the impact of technological resource commitment[1] (i.e., greenfield, born global, incubator, and technological network/strategic group/alliance), which is regarded as the source of bargaining power possessed by the HQ, subsidiaries, or partners (Agnihotri et al., 2022; Ripollés and Blesa, 2017; Wang et al., 2019). According to RDT, power stems from the dependence of one unit on another, since the latter controls key resources (Li et al., 2021; Lin, 2019; Ma et al., 2021). However, the determinants of the bargaining power of an MNC on its control mechanisms have been somewhat ignored in the literature. The research gaps are shown in Fig. 1.

In the study of the HQ–Sub relationship, there is a distinction between wholly owned and partly owned or joint venture subsidiaries. The desire to control (wholly owned) is one aspect, and the power to control (partly owned or joint-venture) is another (Agnihotri et al., 2022; Brouthers and Hennart, 2007). Subsidiaries do not usually act in the best interest of MNCs nor do they comply with the rules and expected motivation determinations (i.e., market-seeking motivation as horizontal FDI and efficiency-seeking motivation as vertical FDI) laid down by the headquarters (Duanmu and Lawton, 2021). This problem is exacerbated by the evolving development of MNCs. The neo-motivation on developing strategic asset-seeking determination (Elia et al., 2019). Strategic asset-seeking is related to technological resource commitment (Ripollés and Blesa, 2017; Wang et al., 2019). While Agnihotri et al. (2022) found that the resources of a subsidiary within a host country might also affect the control mechanisms exercised by the parent company, they did not specify the origin of such resources. Other studies on control mechanisms have the same tendency of focusing on the resource commitment of one party only, such as how manufacturers deal with sales representatives in the local context of the host country (Oliver and Anderson, 1994), how exporting firms manage foreign distributors in the supply chain (Miller et al., 2009; Tse et al., 2019), and how parent firms control international joint ventures (Luo et al., 2001; Yan and Gray, 2001; Yan and Child, 2004a, 2004b). Accordingly, studies in agency literature overlooked the impact of technological resource commitment on control mechanisms by the three sources simultaneously: the headquarters, the subsidiaries, and the business partners in joint ventures and the supply chain. Therefore, this study highlights the literature in this field by providing a better understanding of the mindset of how MNCs fine-tune their global configurations and make decisions related to HQ-Sub relationships. This study also investigates the association of different FDI motivations with the control mechanisms adopted by the parent HQs. This study, thus, aims to explore how FDI motivations and resource commitment influence the use of control mechanisms in an MNC. We make two contributions. First, we integrate agency theory and RDT to examine two determinants affecting HQ–Sub relationship in our study: (1) resource-seeking and market-seeking FDI motivations of the parent firm and (2) technological resource commitment, which originates another three determinants, from the HQ, the Sub and the business partners in joint ventures and the supply chain. Our findings shed light on this line of research and suggest managerial implications that require MNCs to revisit their control mechanisms in order to achieve business growth.

Second, this study aims to fill the above-mentioned gap by examining the HQ-Sub relationships of 1015 Taiwanese manufacturing multinationals operating in China (newly industrialized economy (NIE) to emerging economy[2]). Most FDI empirical studies in literature used data related to FDI flow from one developed country to another, the number of FDI studies in the reverse direction is far less (i.e., from NIEs and emerging economies to developed countries) (Luo, 2001; Filatotchev et al., 2007; Yang and Mohammad, 2023). Therefore, it is important to determine whether findings based on analysis of MNCs whose investments flow between NIEs and emerging economies could have the same applicability as suggested in existing literature (Yang and Mohammad, 2023). It is rare for an emerging economy such as China to experience deglobalization due to lockdowns, while also having the U.S. seeking to remove its "developing country" status (Fox Business, 2023). The DHL Global Connectedness Index (2022) gauges the extent of countries' connection with the rest of the world, which reached its peak in 2007, but has been gradually declining, and the index reached its lowest level since 2001. We are motivated to trace back to the inflection point of the year 2003[3]. By doing so, this study offers managerial implications for HQ based in NIEs to determinate effective control mechanisms over their subsidiaries in emerging economies. These implications are particularly relevant in an institutional environment characterized by high rates of economic growth but vastly different political and economic settings, as highlighted by prior research (Luo, 2003; Kaufmann and Roessing, 2005).

The remainder of this paper is structured as follows: First, we reviewed the existing literature and developed our research hypotheses; second, we described our research methodology; third, we showed our empirical results; fourth, we discussed our findings and presented our conclusions, as well as the limitations of the research and possible topics for future research.

Literature review and hypotheses

Agency theory and process control. According to agency theory, incongruity of interests and information asymmetry exist in most relationships between headquarters (i.e., the principals) and subsidiaries (i.e., the agents) (Eisenhardt, 1989; Jensen and Meckling, 1976). Given the fact that principals and agents are assumed to be self-interested and characterized by bounded rationality, this incongruence of interests, along with the fact of cultural distance, means that subsidiaries' actions do not always align with those that might be considered optimal by headquarters (Chatzopoulou et al., 2021). Thus, headquarters must

Table 1 RQ-Sub relationship literatures.

Author (year)	Theory/ perspective	HQ-Sub relationship/type	Independent variable	Moderator	Dependent variable	Finding
Moalla and Mayrhofer (2020)	N.A.	Network/ Merger-Acquisition/ Cooperative Alliance	Cultural distance/ Administrative distance/ Geographic distance/ Economic distance	N.A.	Merger-Acquisition/ Cooperative Alliance	The findings indicate that administrative and economic distance has a significant influence on market entry mode choice, whereas the impact of cultural and geographic distance is not significant.
Wang et al. (2019)	RBV	Political connection/ Network/ Greenfield/ JV/ Acquisition	Firm technological capabilities/Industry technological capabilities/Political connections	N.A.	R&D entry mode	The study showed that strong political connections at home encourage Greenfield investments. Strong technological capabilities have a relatively little direct impact but interact with political connections to encourage Greenfield investments.
Lin (2019)	Resource dependence theory	Network/ The % shareholding taken by headquarters in its foreign affiliates	Cultural distance/ Geographic distance/ Institutional distance	N.A.	Business group headquarters' ownership in foreign affiliates	The results show that the equity stakes of the BG headquarters in the group-affiliated firms in foreign markets were positively associated with the geographic distance between the country of the BG headquarters and the host country of the foreign group-affiliated firms.
Schwens et al. (2018)	N.A.	Entry mode/ Export/Non-FDI contractual/JVs /WOS	The intensity and diversity of SMEs' operation mode experience	Target market/ region-specific experience	Entry mode choice	We find that a unit increase in intensity and diversity of export experience significantly increases SMEs' propensity to choose export in a new foreign market. We also find that greater intensity or diversity of WOS experience increases SMEs' propensity to choose a WOS in a new foreign location.
Duanmu and Lawton (2021)	Agency theory	Motivation/ OS/JV/	Foreign buyouts with efficiency-seeking/ Foreign buyouts with CEO succession	N.A.	Performance improvement	We provide micro evidence that superior post-buyout performance is observed in converted WOSs with efficiency-seeking operations and subsequent CEO succession. The findings extend our understanding that ownership per se does not guarantee performance improvement.
Wan et al. (2023)	RBV/TCE	Entry mode/ WOS/JV/ Greenfield/ Acquisition	Parent-firm characteristics/ Host-country/ Parent-foreign affiliate differences/ Home-host country differences	Time of study/ Home-country type/Journal level/Entry mode measurement	Entry mode/ Post-entry outcomes	The ownership mode and establishment choice had significantly positive effects on survival. The results showed that establishment mode and ownership mode worked differently as mediators.
Mas-Ruiz et al. (2018)	Institutionalist perspective	Network/ WOS/JV/other alliance	The mimetic entry by firms of the strategic reference group	The firm's host country experience	Foreign entry mode	Our results reveal imitation behavior between members of the strategic group and highlight the important role of the strategic group in strategic thinking.

Author (year)	Theory/ perspective	Entry mode	Independent variable	Moderator	Dependent variable	Finding
Albertoni et al. (2019)	N.A.	Entry mode/ Outsourcing/ Captive	The repetition of previous entry modes/The inertial and the mindful repetition of the entry-mode choice	N.A.	Entry mode	Results confirm that firms tend to replicate the previous entry modes of the same type. In particular, the mindful entry-choice model shows that firms tend to repeat past successful experiences.
Li et al. (2020)	N.A.	Entry mode/ WOS/JV	Foreign market entry	N.A.	The performance effect of the entry mode choices in different subnational regions	The smaller performance gap between wholly owned subsidiaries and joint ventures in the developed region indicates that the magnitude of influence of entry mode choices on performance varies across subnational regions.
Ma et al. (2021)	Social network theory	Political connection/ Entry mode/ WOS/JV	Political ties	Entry mode/ Industry restriction	Firm performance	The findings support the hypotheses that the impact of political ties on firm performance is contingent on firms' ownership-based entry modes and industry restrictions. In particular, the impact of political ties is stronger for joint ventures (JV) in less restricted industries and wholly owned subsidiaries (WOS) in more restricted industries.

Table 1 (continued)

Author (year)	Theory/ perspective	Entry mode	Independent variable	Moderator	Dependent variable	Finding
Lu et al. (2018)	TCE	Political connection/ Entry mode/ JV/WOS	Political hazards	Host country experience/ Foreign aid	Foreign entry mode choice	We find that Chinese firms tend to use the joint venture mode when political hazards are high in an African country. This relationship is weakened when they accumulate host country experience and when the Chinese government's foreign aid to an African country increases.
Li et al. (2021)	Stakeholder perspective and TCE	Entry more/ WOS/JV	Entry mode of new foreign direct investment	Firm's Transparency /External Control of corruption.	Freedom of digital media	Our empirical analyses indicate that freedom of digital media in a host country has a positive impact on an EMNE's wholly owned subsidiary choice as an FDI entry mode. This main relationship is strengthened by EMNE transparent information disclosure and external control of corruption in the host country.
Tse et al. (2021)	Complementary asset theory	Entry mode/ Network/ JV/WOS	Local R&D investment	Local government support/ MNEs' entry mode	Innovation performance of local subsidiaries	We show that: (a) local government support positively moderates the effect of foreign firms' local R&D investment on their local subsidiaries' innovation performance in China; (b) this relationship is stronger for IJVs than for WOSs; and (c) local government support appears to have a stronger moderating effect for IJVs than for WOSs on this relationship.
Amankwah-Amoah et al. (2022)	Knowledge-based view and Upper echelons theory	Equity modes/ Non-equity modes	Foreign market knowledge	Financial slack	Foreign entry mode choice/ International performance	The results reveal that FMK and international performance relationship is mediated by foreign market equity entry mode choice. The results also suggest that FMK positively relates to SMEs' preference for equity mode for foreign market entry and this relationship is amplified when slack resource is greater.
Li et al. (2017)	N.A.	Political connection Entry mode/ WOS/JV	Linkage capability/ Leverage capability/ Learning capability	Cultural Distance/ Market Potential/ Institutional Distance	Entry mode choice	The results show that multinational firms from emerging markets (EMFs) with stronger LLL capabilities are more likely to choose the wholly-owned mode in foreign entries. The relationship between linking capability and wholly-owned entry mode choice is weaker at higher levels of cultural distance between home and host country.
Ripollés and Blesa (2017)	TCE/ Organizational capabilities-based perspectives	Equity modes/ Network/ Non-equity modes	The need for after-sales service in foreign markets/The technological complexity of international new ventures' products/services /Inter-firm network management activities	N.A.	Entry modes	Our findings show that the technological complexity of INVs' products/services explains their preference for equity entry modes. Additionally, the development of network management activities among the networked firms determines the INVs' preference for non-equity entry modes.
Agnihotri et al. (2022)	Contingency theory	Entry mode/ Network/ JVs/WOS/ Exports /Licensing	Servitization through customer relationship/ Servitization through digitalization strategy	National cultural differences in the home versus host country	Entry modes	Based on the extant literature, using a 2*2 matrix, the authors delineate the influence of two dimensions of servitization on entry mode decisions: customer relationship focus and digitalization focus. They conceptualize that relationship management and digitalization-based servitization have an antagonistic effect on the need for entry-mode resource commitments, and macroenvironmental factors' favorability moderates this tension.

Table 1 (continued)

Author (year)	Theory/ perspective	Entry mode	Independent variable	Moderator	Dependent variable	Finding
Elia et al. (2019)	TCE/RBV/ Knowledge-based view	Network/ Outsourcing/ Partnering/ teaming arrangement/ Captive	Business functions modularity/ Functional fine-slicing/ Offshoring experience	N.A.	Entry mode hierarchy	Modular activities are more likely to be outsourced, as modularity decreases transaction costs and knowledge leakage risks, while not-modular activities reflect captive entry modes. We argue that firms can "break" the mirror as the entry choice is contingent upon the level of disintegration of the value chain and the offshoring experience of the firms.

N.A. not available, *RBV* resource-based view, *JV* joint venture, *TCE* transaction cost economies, *INV* international new venture, *WOS* wholly owned subsidiary.

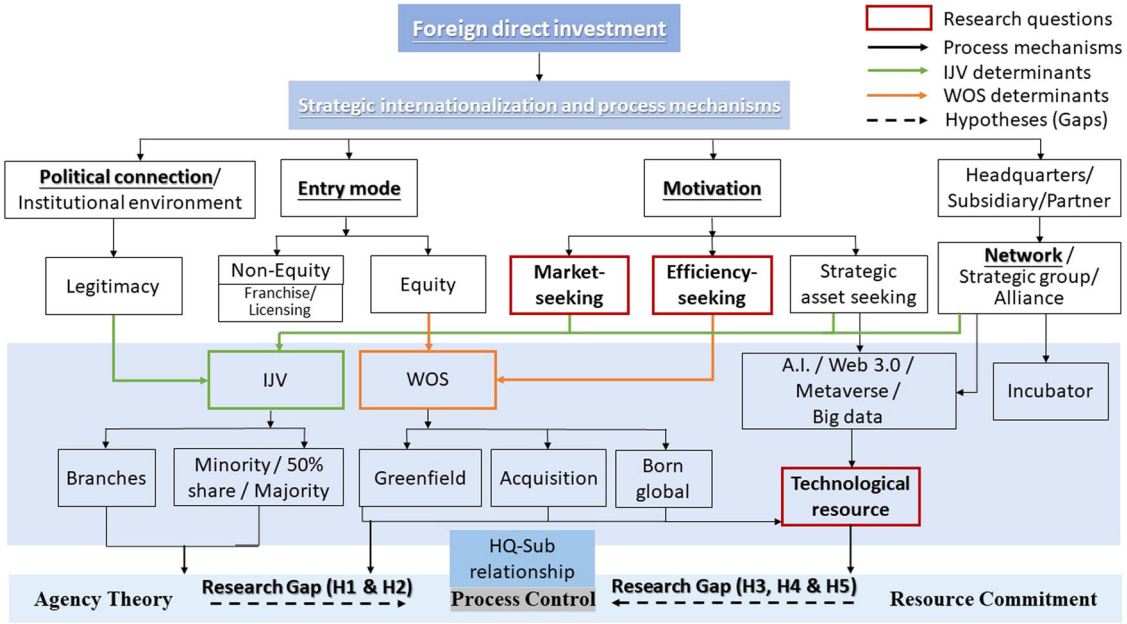

Fig. 1 FDI process control mechanism development framework. HQ-Sub headquarters-subsidiary, IJV international joint venture, WOS wholly-own subsidiary, A.I. artificial intelligence.

work to reduce potential agency problems by means of control mechanisms (Egelhoff, 1984; Ouchi, 1977).

Earlier studies engaged in the classification of control mechanisms. Two main typologies, which represent a significant portion of control-related issues, are equity ownership and behavioral control mechanisms. This study focuses on behavioral control mechanisms (e.g., process and outcome control), which are mechanisms originally introduced by agency theorists (Eisenhardt, 1989; Egelhoff, 1984; Ouchi, 1977) and refer more to the actions taken to monitor or influence the operations of subsidiaries (Eisenhardt, 1989; O'Donnell, 2000). In addition, behavioral control can be flexibly adapted according to the needs of a particular context of operation or business practices. In contrast, equity ownership is difficult to change due to high switching and negotiation costs (Luo, 2001). To reap greater benefits and reduce the risks associated with the uncertainties presented by emerging economies, MNCs should exercise carefully-crafted behavioral control mechanisms (i.e., process and outcome control), in addition to owning equity.

The presence of process control indicates that a headquarters closely monitors and attempts to influence the operations of a subsidiary, whereas the exercise of output control suggests that a headquarters is more focused on the evaluation of subsidiary performance. While some researchers treat process and output control as dichotomous, others suggest that the two types of control exist along a continuum (Oliver and Anderson, 1994). Hennart (1991) argued that in practice, the two are likely to be used as substitutes for one another, rather than as complements. If process control becomes too costly to implement, headquarters may shift to output control. Therefore, in this study, we treat process control as our dependent variable without the inclusion of output control. Similarly, Gencturk and Aulakh (1995) also operationalized process and output control by means of the same measurement devices but employed a reversed coding. Surprisingly, process control has been the subject of fewer empirical tests, especially in the context of MNCs (for exceptions, see Gencturk and Aulakh, 1995; O'Donnell, 2000; Yu et al., 2006).

Motivation. Given that subsidiaries run operations overseas on behalf of MNCs, an understanding of the motivations behind headquarters' engagement in FDI may be useful in the design of control mechanisms and the management of subsidiaries (Makino et al., 2002; Nachum and Zaheer, 2005). A number of studies have examined control issues associated with two of the most critical objectives of headquarters: the global integration of

operations and responsiveness to the local market served (Gooch et al., 2022; Jarillo and Martínez, 1990; Luo, 2001). Global integration leads to a higher level of control, while local responsiveness produces the opposite effect (Doz and Prahalad, 1984). While several studies have produced evidence supporting this division between global integration and local responsiveness (Jarillo and Martínez, 1990), Doz and Prahalad (1984) noted that the choice between these two objectives is not necessarily of the "either-or" variety. Further, the decision to move toward global integration may be the result of various motivations. In addition, while several studies have claimed that MNCs pursuing global integration would likely exercise a high degree of control over their subsidiaries in terms of equity ownership (Luo, 2001; Bartlett, 1986; Jarillo and Martínez, 1990), these studies have not explicitly examined how the resource-seeking motivation is related to global integration and how this particular type of motivation affects process control (see Edwards et al. 2002, for an exception). Therefore, it may be more productive to test ex-ante classifications of the motivations for FDI for their ex-post effects rather than attempting to infer motivation from observed effects (Liu et al., 2023). Specifically, in this study, it is the market and resource conditions in host markets and the relationship between those conditions and the motivations of a parent firm that influence the need for integration and responsiveness (Doz and Prahalad, 1984; Hao, 2023).

Given that emerging economies are typically characterized by a lack of advanced technologies, foreign firms operating in such economies are often motivated by the desire to make use of low-cost production resources or by the hope of gaining a large share of a huge untapped market (Lecraw, 1993). Therefore, our examination focuses on the effect of resource-seeking and market-seeking motivations on the control mechanisms that headquarters choose to employ.

Resource-seeking motivations. Resource-seeking motivations in emerging economies typically include access to natural resources, raw materials, land, and workforce; such motivators are generally characterized by lower costs in a particular host country and are usually either immobile or prohibitively costly to transfer across national boundaries (Dunning and Lundan, 1993). According to agency theory, the question of whether resource-seeking motivations lead to the use of process control may be evaluated according to three criteria: lower monitoring costs, less conflict over goals, as well as, a greater degree of task programmability; these lead to more frequent use of process control. Otherwise, output control will be more frequently used (Eisenhardt, 1989; O'Donnell, 2000). In a case study of Korean and Taiwanese electronics manufacturers with subsidiaries in NIEs, Van Hoesel (1999) found that parent firms chose to locate labor-intensive manufacturing activities in developing countries with abundant labor forces, whereas they tend to locate their final goods assembly processes in developed countries. Such arrangements are designed to achieve economies of scale in each subset of the firm's value activities. In such circumstances, a headquarters may opt for tight process control when it comes to subsidiaries' strategic and functional activities. Additionally, because the development of subsidiaries is directed by headquarters, the amount of goal-related conflict can be limited, and task programmability can be improved. Taken together, resource-seeking motivations induce headquarters to utilize process control.

Also, the utilization of inexpensive local resources helps firms to gain market share by enabling them to produce goods at lower costs and by facilitating their adaptation to local institutional environments. Although subsidiaries are often able to exploit local resources to facilitate manufacturing efficiency, offshore production generally necessitates the reconfiguration of production facilities, which require headquarters to inject their own useful experience into manufacturing and management processes. In a situation in which a headquarters has well-established manufacturing regimens in its home country, tight process control mechanisms are suitable for the regulation and scheduling of overseas manufacturing activities (Brown et al., 2003). Similarly, Nobel and Birkinshaw (1998) suggested that a headquarters should be prepared to exercise fairly tight control (i.e., by means of centralization) if cost efficiencies are to be achieved. Therefore, the first hypothesis of our study is given as follows:

Hypothesis 1. The likelihood that a headquarters will use process control is high if the primary motivation for setting up a subsidiary in a host country is resource-seeking.

Market-seeking motivations. Firms' market-seeking motivations in emerging economies may be related to high market growth rates, government policies designed to encourage FDI and import barriers on foreign-made goods (Lecraw, 1993; Makino et al., 2002). Studies have found that the seeking of new markets is related to partial equity ownership in the cases of the global hotel industry (Brown et al., 2003) and the subsidiaries of MNCs based in the United States (Lecraw, 1984). Except for Edwards et al. (2002), most existing studies focusing on this phenomenon did not emphasize the issue of process control.

In situations when firms' motivations are essentially market-seeking, subsidiaries are afforded significantly more opportunities to interact with local institutions; thus, they become familiarized with local customers, legal requirements, and marketing procedures. Although headquarters may be equipped with some knowledge of a local market as a result of their own international operations, in-depth knowledge of a host country is difficult to gain without personal interaction in the local context, especially with respect to emerging economies. If strategic flexibility is to be enhanced, the decisions to act and respond need to be made at the local level (Sarkodie et al., 2022). In such situations, it would seem that a high degree of information asymmetry or high monitoring costs would induce a headquarters to exercise a lesser degree of process control over its subsidiaries. Also, subsidiaries managed by expatriates are more likely to act to maximize short-term profits for their private benefit in capturing local market share rather than working to maximize collective profits for the benefit of the corporation as a whole. While a headquarters may well understand that subsidiaries are, to some extent, not entirely trustworthy, the enormous competitive pressures that accompany entry into new markets mean that headquarters must rely on subsidiaries within local markets. Thus, the potential for conflict over goals will act to reduce the extent to which a headquarters exercises process control. Nevertheless, research has generally acknowledged that emerging economies are less economically and institutionally developed than their developed country counterparts (Yang and Mohammad, 2023). It is important to note that the increasing influence of globalization may be impacting these factors in ways that are not yet fully understood (Fazi, 2023). Such conditions would suggest that the tasks required of subsidiaries are less programmable. To help mitigate these uncertainties, subsidiaries need to have greater levels of flexibility so that they can effectively deal with various contingencies in a timely manner. Thus, a lesser degree of process control may be preferential in the management of the HQ–Sub relationship in this situation.

Hypothesis 2. The likelihood that a headquarters will use process control is low if the primary motivation for setting up a subsidiary in a host country is market-seeking.

Resource commitment. While different motivations may affect the choice of control mechanisms, the resource dependence perspective holds that the use of control mechanisms is to some extent related to the party that provides certain critical resources (Li et al., 2021; Lin, 2019; Ma et al., 2021), such as technological resources, which was considered in this study. According to Kostova et al. (2016), the continuous development of technologies is critical to an MNC. The role of technology transfers or commitment in the balance of power between HQs and subsidiaries is always challenged. The party contributing critical technological resources associated with the required know-how for handling manufacturing processes and production (Kaufmann and Roessing, 2005) will enjoy superior bargaining power. Several studies have suggested that proprietary technological resources committed to subsidiaries by headquarters (Buckley and Casson, 1976; Dunning and Lundan, 1993) can be used to wield control in bargaining situations, such as in the determination of shares of equity (Chen and Hennart, 2002) or the structuring of information feedback (Yan and Child, 2004b). However, recent research has argued that technological assets may be developed and contributed by subsidiaries themselves rather than the headquarters (Birkinshaw and Hood, 1998; Lee et al., 2020). In such cases, these resources may well inspire subsidiaries to direct and control their own behavior and strategic development (Nobel and Birkinshaw, 1998).

When the internal resources of a headquarters or subsidiary are not enough for a firm to maintain its competitive edge, collaboration with external parties to acquire complementary or supplemental resources is needed. Some scholars have emphasized that local partners' resource commitment may also serve as a source of technological knowledge and may have an impact on control mechanisms, such as in the case of international joint ventures (Yan and Gray, 2001; Yan and Child, 2004a 2004b). Although these studies provided evidence regarding the impact of resource commitment on the use of control mechanisms, only a few of them empirically tested the impact of partners' resource commitment on the relationship between a headquarters and its subsidiaries. In this study, the partners in question may be joint venture partners contributing technological resources or local firms providing technological expertise. Further, very few studies have simultaneously examined the impact of three different sources (headquarters, subsidiary, and local partner) of technological resource commitment on the use of control mechanisms by a headquarters.

Technological resource commitment by a headquarters or subsidiary. Recent studies point to the role of technology transfer in the balance of power between headquarters and subsidiaries. It is expected that when technological resources are contributed by a headquarters, the resultant bargaining power will result in the headquarters exerting process controls over its subsidiaries (Chen and Hennart, 2002; Mjoen and Tallman, 1997). Further, the use of process control by a headquarters is likely to increase the efficiency of technological resource exploitation and the effectiveness of knowledge transfer within firms (Mjoen and Tallman, 1997), as the headquarters will likely have a better understanding of the appropriate application of valuable resources to marketing and production processes. Finally, process control is bolstered by headquarters to prevent imitation of their know-how and preclude opportunistic behaviors on the part of their subsidiaries. Similarly, Luo (2001) suggested that headquarters would likely make use of wholly owned subsidiaries in order to safeguard their proprietary resources.

In contrast, if the technological resources are contributed by a subsidiary, the use of process control will likely be reduced. This is because subsidiaries will have the bargaining and decision-making power required to direct their own operations, the knowledge to effectively use these resources, and the desire to protect their own know-how (Valorinta et al., 2011). Further, subsidiaries may utilize their knowledge to cultivate relationships with other partners, such as governmental authorities. These relationships provide access to valuable information, which in turn further enhances subsidiaries' bargaining power, especially in emerging economies where interpersonal relationships are often of paramount importance.

Hypothesis 3. A headquarters' technological resource commitment is positively related to its use of process control in managing its subsidiary in a host country.

Hypothesis 4. A subsidiary's technological resource commitment is negatively related to its headquarters' use of process control.

Technological resource commitment by a partner. While technological resource commitment by a partner should increase the partner's bargaining power (Elia et al., 2019), we postulate that the technological resources committed by a partner will result in a reduction in the use of process control by the headquarters. We provide three reasons for making this postulation. First, the commitment of technological resources to a subsidiary implies that a partner has a significant interest in the development of the subsidiary (Ripollés and Blesa, 2017). Accordingly, a lower level of process control will enable the subsidiary to pursue its own interests, rather than only those of the headquarters. Second, technological resources are characterized by complexity (Ripollés and Blesa, 2017) and require intense communication between a partner and a subsidiary (Tse et al., 2021). With regards to facilitating a subsidiary's rapid absorption of a partner's resources as well as their efficient exploitation, a reduction in the use of process control would lead to optimal results (Duanmu and Lawton, 2021). Third, the resources committed by a partner attain enhanced importance in situations of local production (Agnihotri et al., 2022). In such situations, improved local operations may increase a subsidiary's bargaining power and lead to the reduced use of process control by the headquarters.

Hypothesis 5. The technological resource commitment of partners is negatively related to a headquarters' use of process control over a subsidiary in a host country.

Methodology

Survey procedure and samples. This research is based on information contained in a database maintained by the Statistics Bureau, Ministry of Economic Affairs, Taiwan, R.O.C. Data were collected through a national survey aimed at investigating the FDI status of Taiwanese manufacturing firms in 2003. This means that our research sample comprises only Taiwanese companies with headquarters in Taiwan. On the basis of the standard industrial classification code (SIC code), published by the Ministry of Economic Affairs (2002), 311 non-manufacturing subsidiaries were removed. Among the 1541 Taiwanese manufacturing firms engaged in foreign investments, 1015 firms with investments in China were selected from the database. FDI is one of the important approaches to overseas expansion that triggers the world economy; it is an entry mode that provides more control over foreign operations and offers a better understanding of the host market for MNEs. Accessing the data from the government survey is difficult due to its outdated nature. However, with the current state of deglobalization, China's FDI policy, and China's removal of developing country status from the U.S., we have been able to persuade the government sector to allow us to adopt the data and include contemporary issues for academically research.

Through this investigation, we aim to provide empirical evidence of the HQ-Sub relationship control process mechanism, which can be insightful for understanding the varied future FDI scenarios. Furthermore, we selected Taiwan as the home country and China as the host country in the year 2003 for the following reasons.

First, at the beginning of the 21st century, the Chinese mainland officially joined the WTO, in December 2001, and entered into a new period of development. Taiwanese companies began to expand their investment into the mainland. According to statistics, from 2000 to 2002, if the amount of investment in the mainland through third parties is included, Taiwanese firms would be the second largest foreign investor in mainland China after Hong Kong (UNCTAD, 2019). Despite its short history of economic liberalization, China has hosted many multinational corporations hoping to acquire resources or serve the local markets (Kaufmann and Roessing, 2005). However, this largest emerging economy, characterized by substantial risks associated with inefficient information and dramatically-shifting market demands, also poses a challenge for foreign firms. In such an environment, the control of Chinese subsidiaries is particularly important, especially for Taiwanese companies that have expanded into China as their main market. Therefore, we used the data from 2003 as our research sample to understand the control relationship between Taiwanese companies and mainland subsidiaries.

Second, from a theoretical perspective, taking samples from an NIE (e.g., Taiwan in this study) helps to examine the application of theories developed in the context of developed countries (Filatotchev et al., 2007). In addition, by entering China, Taiwanese firms also face challenges in their international operations (Filatotchev et al., 2007). From a practical viewpoint, observing the control mechanisms of the Asian model of NIE firms might provide some insights for Western firms, as they seek to enact appropriate control mechanisms. While Taiwan and China share a similar culture and language, political friction between them provides an additional dimension of risk to Taiwanese firms with FDI in China (Filatotchev et al., 2007). Also, Taiwan is similar to many other countries in South East Asia, such as Indonesia, Malaysia, Thailand, Singapore, Hong Kong, and Macau; therefore, the ways in which Taiwanese firms select and use control mechanisms to overcome possible economic and political risks may have implications for other foreign firms with international operations in China. For these reasons, we hold the opinion that the use of Taiwanese data was appropriate.

Measurements

Dependent variable. *Process control* (*Pcontrol*) refers to the extent to which a headquarters influences the operations of a subsidiary (Eisenhardt, 1989; Gencturk and Aulakh, 1995). This study used five items to represent process control: business strategy, pricing strategy, marketing strategy, personnel policy and financial strategy (Edwards et al., 2002). The items were measured according to the following code: 3 represents "determined by the headquarters," 2 represents "jointly determined by the headquarters and the subsidiary," and 1 represents "determined by the subsidiary." The five items were summed as a measure of process control, and values ranging from 5 (the lowest level of process control) to 15 (the highest level of process control) were obtained. The five items showed a high degree of internal validity (Cronbach alpha was 0.91). Factor analysis further confirmed that there was only one dimension (loadings were 0.80, 0.91, 0.92, 0.82, 0.82, respectively).

Independent variables. Used in this study included two motivation-related variables and three sources of technological resource commitment. *Resource-seeking motivation (Resource)* refers to the search for land, workers, and raw materials as a headquarters' motivation for investing in a host country (Dunning and Lundan, 1993; Makino et al., 2002; Nachum and Zaheer, 2005). The following three questions were used in our survey: (1) the headquarters invested here because the land acquisition was easy; (2) the headquarters invested here because of the inexpensive and plentiful supply of raw materials; and (3) the headquarters invested here because of the plentiful supply of labor and low wage rates. Each item was coded as 1 if the response was "yes" and 0 if the response was "no". We then summed the three items to get a score ranging from 0 to 3. The higher the score, the stronger the resource-seeking motivation is.

Market-seeking motivation (Market) means that serving the local market was a headquarters' primary motivation for investing in a host country (Dunning and Lundan, 1993; Makino et al., 2002; Nachum and Zaheer, 2005). We used three items to reflect this motivation (coded as 1 if "yes" and 0 if "no"): (1) headquarters chose to invest here because of the significant market potential; (2) headquarters chose to invest here because of the incentives offered by the host government; and (3) headquarters chose to invest here to avoid high import tariffs or trade barriers. The summation of respondents' answers to these three items generated a score ranging from 0 to 3. The higher the score, the stronger the market-seeking motivation is.

A headquarters' technological resource commitment (Htrc) indicates the extent to which a headquarters contributes technological resources to its subsidiary. Four items were included in this category, with 1 indicating "yes" and 0 indicating "no": (1) the most important technologies for the subsidiary are provided by the headquarters; (2) the headquarters provides manufacturing equipment to the subsidiary; (3) the headquarters provides raw materials to the subsidiary; and (4) the headquarters provides components or semi-manufactured goods to the subsidiary. We then summed the 4 items together to get a score ranging from 0 to 4.

A subsidiary's technological resource commitment (Strc) focuses on the technological resources contributed by a subsidiary. Five items were included, with 1 representing "yes" and 0 indicating "no": (1) the most important technology for the subsidiary is developed by the subsidiary itself; (2) the subsidiary purchases raw materials locally; (3) the subsidiary purchases components and semi-manufactured goods locally; (4) the subsidiary has its own research and development department; and (5) the subsidiary has its own design department. These five items were summed, with scores ranging from 0 to 5.

Partners' technological resource commitment (Ptrc) examines the commitment of technological resources by local partners. Three items are included, with 1 representing "yes" and 0 indicating "no": (1) the most important technologies for the subsidiary are provided by the partners; (2) the most important technologies for the subsidiary are the result of learning from the partners; and (3) the most important technologies for the subsidiary are developed with partners. These three items were summed, with scores ranging from 0 to 3.

Control variables. Involving characteristics at the parent-firm level, the subsidiary level, and within the host country environment, are likely to affect a headquarters' choice of process control. We provide no formal hypotheses for these factors but control for their impacts in our model. First, we provided control for *multinational corporations' size* (*Msize*), presented as the natural logarithm of the number of employees within the entire multinational corporation, and *multinational corporations'*

international experience (*MIexp*), presented as the natural logarithm of the ratio of foreign sales to the entire multinational corporation's sales. Regarding *multinational corporations' R&D expenses (MR&D)* related to a headquarters' capabilities, as measured by the total investment amount in technological R&D. We took the natural logarithm (huge number) within the total amount of technological R&D. *Entry mode (Emode)* was measured as the percentage of subsidiary equity controlled by the headquarters. We classified a subsidiary as wholly-owned if the percentage of ownership by the parent firm was greater than 95%, which we coded as 1; otherwise, we classified the subsidiary as a joint venture, a definition adopted by numerous other studies, and we coded it as 0 (Agnihotri et al., 2022). *Subsidiaries' fixed asset investment intensity (SFAII)* was measured according to the fixed asset investment by subsidiaries as a share of the whole multinational corporation's fixed asset investments. *Subsidiaries' experience (Sexp)* indicates the number of calendar years since the subsidiary was established, and it allowed us to provide control for age and experience. The *importance of subsidiary in group (ISG)* was measured according to the ratio of assets of headquarters to assets of subsidiary.

With respect to host country-related variables, the variable of *government restrictions on the ratio of imports and exports (GRIM)* was coded as 1 if it presented a barrier to headquarters; otherwise, it was coded as 0. The variable of *government restrictions on equity (GRE)* that could be held by foreign firms was coded as 1 if it served as a barrier to headquarters; otherwise, it was as coded 0. The variable of significant *differences in social customs and business practices (DSCBP)* between the home country and the host country was coded as 1 if it was perceived as a barrier to headquarters; otherwise it was coded as 0. Also, *inefficiency of the local government (ILG)* that was generally considered a barrier for headquarters was coded 1; otherwise, it was coded 0. *Insufficient local infrastructure (ILI)* that was perceived as a hurdle for headquarters was coded as 1; otherwise it was coded as 0. The *non-availability of qualified expertise and technological mechanics* (*NQETM*) was coded as 1 if it presented a challenge to headquarters; otherwise, it was coded as 0. Similarly, *uncertainty of home country legal framework (UHCLF)* perceived as a business operation uncertainty for headquarters was coded as 1; otherwise it was coded as 0. Finally, we classified parent firms into four industries: *metal and machinery (MM)*, *chemicals and plastics (CP)*, *food, textile and others (FTO)*, and *information and electronics (IE)* industries. The information and electronics industry was used as a reference group, and three dummy variables were set to distinguish the industry's effect on process control.

Results

Table 2 reports the means, standard deviations, and correlations among the data for this model and the control variables. Linear regression analysis was used to investigate the question of whether differences in motivation influence the level of process control exerted by headquarters as well as the question of whether technological resource commitment influences process control (Table 3). After removing multicollinearity between independent variables by a mean-centered approach (Aiken and West, 1991), hierarchical regression analyses were performed. Model 1 was statistically significant ($F = 8.17$, $p < 0.01$), providing evidence that the control variables accounted for 13% of the variance in process control. This suggests, in turn, that we are justified in including these variables in our analysis.

Model 2 adds our hypothesized motivation effects to the previous model. In support of Hypothesis 1, resource-seeking motivation is positive and highly significant ($\beta = 0.08$, $p < 0.01$ in Model 2). The impact of market-seeking motivation on process control appears to be negatively significant ($\beta = -0.12$, $p < 0.01$ in Model 2), which support Hypothesis 2. Hypothesis 3, which predicted that the technological resources committed by a headquarters would be positively related to process control, is supported here ($\beta = 0.16$, $p < 0.01$ in Model 3). Hypothesis 4, which puts forth the expectation that a subsidiary's technological resource commitment would lead to a lesser degree of process control from a headquarters, was supported ($\beta = -0.14$, $p < 0.01$ in Model 3). We found that the commitment of partners' technological resources was negatively associated with process control ($\beta = -0.11$, $p < 0.01$ in Model 3), in conformity with the expectation stated in Hypothesis 5. In Model 4, we included all independent variables, and the results are consistent with the findings of Model 2 and Model 3. In summary, resource-seeking motivations, market-seeking motivations, and technological resource commitment by a headquarters, a subsidiary, and a partner are all salient factors in explaining the process control implemented by a headquarters. Finally, we summarize the results of five hypotheses in Fig. 2.

In addition, our test results indicate that the control variables such as entry mode (Emode), government restrictions on equity (GRE), inefficiency of the local government (ILG), subsidiaries inexperience (Sexp), and type of industry (MM, CP and FTO) appear to have impacts on MNC's use of process control.

In order to ensure the robustness of the results, several tests were conducted. First, the sample was divided into two subsamples according to median sales, one including the smallest 50% of firms and the other the largest 50%. Comparison of the results of the two subsamples indicated that they were almost the same, although the significance of the sample of small firms in the variable *Msize* was decreased to $p < 0.1$. The overall results for both subsamples were the same. Next, the sample was also divided into two subsamples in terms of the type of industry: one was the information and electronics industry and the other was the non-information and electronics industry. Comparison of the results of the two subsamples indicated that they were also very similar. Finally, MNCs total assets (log-transformed) were further used as an alternative measure of MNCs size. Also, in this case, the results did not change, further corroborating the hypotheses.

Discussion

This paper examined the impact of various factors of agency theory and resource dependence perspective on headquarters' employment of process control over subsidiaries with respect to FDI from NIE firms to emerging markets using a sample of Taiwanese MNCs investing in China. We advance existing research on FDI by arguing that entering into emerging markets exposes the investing firm to a business environment of information asymmetry.

Because the interests and goals of the headquarters and its subsidiaries may differ, the headquarters is likely to exercise control mechanisms over its subsidiaries. Appropriate control mechanisms help parent firms to acquire country-specific advantages and prevent the leakage of their resources to competitors. This study, based on agency theory and the resource dependence perspective, identifies two factors, namely FDI motivation and resource commitment, that influence headquarters' decision to use process control. These two factors are the crucial elements behind the headquarters' decision to engage in overseas investment and the origin (i.e., headquarters, subsidiary, or partners) of technological resources.

Two general contributions to previous research are made here. First, the evidence emerging from this study shows that resource-seeking motivations cause headquarters to exercise a greater

Table 2 Correlation matrix and descriptive statistics ($n = 1015$).

	Mean	SD	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17.	18
1. Pcontrol	10.35	3.53	1.00																	
2. Resource	1.07	0.81	0.07*	1.00																
3. Market	0.75	0.63	−0.11*	0.06*	1.00															
4. Htrc	3.06	1.03	0.16**	0.14**	−0.08*	1.00														
5. Strc	2.9	1.49	−0.17**	0.18**	0.05	0.19**	1.00													
6. Ptrc	0.22	0.47	−0.19**	0.03	0.07*	−0.07*	0.16**	1.00												
7. Msize	2.13	0.6	0.11**	0.10**	0.05	0.07*	0.07*	−0.09**	1.00											
8. MR&D	3.79	0.89	0.15**	−0.02	0.11**	−0.07	−0.13**	−0.17**	0.04**	1.00										
9. Emode	0.66	0.47	0.22**	0.06	0.01	0.19**	0.04	−0.16**	0.10**	0.06	1.00									
10. SFAII	0.32	0.29	0.01	0.22**	−0.08*	0.21**	0.19**	−0.02	0.16**	−0.11*	0.10**	1.00								
11. GRIM	0.04	0.21	0.06	0.09**	−0.04	0.01	−0.03	−0.02	0.02	−0.06	0.06*	0.09*	1.00							
12. GRE	0.08	0.27	0.10**	−0.01	−0.01	0.08*	0.01	−0.00	0.01	0.06	0.05	−0.01	0.06	1.00						
13. DSCBP	0.18	0.38	0.03	0.01	0.07*	−0.05	−0.05	0.06*	−0.06*	−0.01	0.00	−0.10*	0.04	0.05	1.00					
14. ILG	0.22	0.41	0.12**	0.06	−0.01	0.08*	−0.07*	−0.01	−0.01	0.02	0.11**	0.00	0.08**	0.08*	0.11**	1.00				
15. ILI	0.07	0.25	0.03	0.01	−0.01	0.01	−0.01	0.04	−0.07*	0.00	−0.00	−0.04	0.02	0.05	0.21**	0.15**	1.00			
16. NQETM	0.39	0.49	0.01	0.04	0.03	0.08*	0.00	0.03	−0.02	0.01	0.02	0.02	0.02	0.10*	0.05	0.07*	0.11**	1.00		
17. MAsset	5.35	0.93	0.09**	−0.02	0.19**	−0.08**	−0.07*	−0.12**	0.60**	0.65**	0.04	−0.14**	−0.03	0.03	−0.01	−0.01	−0.05	−0.01	1.00	
18. Sexp	2.80	0.23	−0.16**	0.17**	−0.06*	0.17**	0.27**	0.08*	0.01	−0.24**	0.04	0.27**	0.02	−0.03	−0.12**	−0.05	−0.09**	−0.01	−0.15**	1.00
19. UHCLF	0.33	0.47	−0.06	0.15**	0.075*	0.06	0.10**	0.08*	−0.05	−0.19**	0.06*	0.10**	0.08*	0.02	−0.01	0.08*	0.06	0.46	−0.14**	0.13**
20. MIexp	0.36	0.31	0.01	0.22**	−0.12**	0.21**	0.17**	0.05	0.12**	−0.17**	0.09**	0.64**	0.09**	−0.04	−0.11**	0.02	−0.01	−0.01	−0.18**	0.38**
21. ISG	0.30	0.28	−0.02	0.20**	−0.09**	0.21**	0.24**	0.06*	0.14**	−0.20**	0.08*	0.75**	0.05	−0.02	−0.10**	−0.01	−0.03	0.01	−0.20**	0.33**
22. MM	0.28	0.45	−0.16*	−0.05	0.04	−0.02	0.05	0.07*	−0.08*	−0.04	−0.08*	−0.09*	−0.1*	0.00	−0.04	−0.08*	0.04	0.06	−0.03	0.00
23. CP	0.18	0.38	−0.05	−0.04	0.02	0.00	−0.01	−0.01	−0.06	−0.10	−0.04	0.06	0.05	0.01	0.03	−0.00	−0.02	−0.03	−0.08*	0.07*
24. FTO	0.18	0.39	−0.04	0.10*	−0.02	−0.04	0.05	−0.00	−0.03	−0.18*	−0.02	0.03	0.02	−0.05	−0.03	−0.01	−0.04	−0.09*	−0.07*	0.14*

	Mean	S.D	19	20	21	22	23	24
1. Pcontrol	10.35	3.53						
2. Resource	1.07	0.81						
3. Market	0.75	0.63						
4. Htrc	3.06	1.03						
5. Strc	2.9	1.49						
6. Ptrc	0.22	0.47						
7. Msize	2.13	0.6						
8. MR&D	3.79	0.89						
9. Emode	0.66	0.47						
10. SFAII	0.32	0.29						
11. GRIM	0.04	0.21						
12. GRE	0.08	0.27						
13. DSCBP	0.18	0.38						
14. ILG	0.22	0.41						
15. ILI	0.07	0.25						
16. NQETM	0.39	0.49						
17. MAsset	5.35	0.93						
18. Sexp	2.80	0.23						
19. UHCLF	0.33	0.47	1.00					
20. MIexp	0.36	0.31	0.19**	1.00				
21. ISG	0.30	0.28	0.16**	0.74**	1.00			
22. MM	0.28	0.45	0.02	−0.11**	−0.05	1.00		
23. CP	0.18	0.38	0.03	0.06	0.05	−0.29**	1.00	
24. FTO	0.18	0.39	−0.01	0.07*	0.05	−0.29**	−0.22**	1.00

Standardized regression coefficients (β) with * if $p < 0.05$; ** if $p < 0.01$.
Msize multinational corporations' size, *MIexp* multinational corporations' international experience, *MR&D* multinational corporations' R&D expenses, *Emode* entry mode, *SFAII* subsidiaries' fixed asset investment intensity, *Sexp* subsidiaries' experience, *ISG* importance of subsidiary in group, *GRIM* government restrictions on the ratio of imports and exports, *GRE* government restrictions on equity, *DSCBP* differences in social customs and business practices, *ILG* inefficiency of the local government, *ILI* insufficient local infrastructure, *NQETM* non-availability of qualified expertise and technological mechanics, *UHCLF* uncertainty of home country legal framework, *MM* metal and machinery, *CP* chemicals and plastics, *FTO* food, textile and others, *IE* information and electronics, *Resource* resource-seeking motivation, *Market* market-seeking motivation, *Htrc* headquarters' technological resource commitment, *Strc* subsidiary's technological resource commitment, *Ptrc* partners' technological resource commitment.

degree of process control over their subsidiaries, while market-seeking motivations have quite a different impact. Resource-seeking motivations are related to the integration of a headquarters' strategic goals, according to which the headquarters may have a strategically pertinent scheme for the organization of their overseas operations. By analyzing Japanese investors' ownership decisions in the United States, Chen and Hennart (2002) found that when access to natural resources was the motivating factor, headquarters would exercise lower levels of control (i.e., forming joint ventures). This result is inconsistent with our findings. In our context of NIE (Taiwanese) firms in an emerging market, subsidiaries may be positioned as offshore production sites for implementing manufacturing cost efficiencies, which require the headquarters to transfer useful experiences into the management process. In such cases, tight process control helps not only to monitor subsidiaries' activities but also to inhibit their opportunistic behaviors.

In contrast, market-seeking motivations are related to accessing market opportunities, thus affording subsidiaries the opportunity to accumulate greater localized knowledge and enabling them to effectively respond to environmental uncertainty. In these circumstances, a lesser degree of process control facilitates subsidiaries' abilities to react with speed and agility. However, Gencturk and Aulakh (1995), using U.S.-based international firms as their sample, found incongruous results, noting that an improvement in the perception of host market attractiveness is associated with increased use of process control by headquarters.

Market-seeking motivations, representing the intention to capture market share, would cause a headquarters to delegate authority to its subsidiaries, enabling the latter to quickly respond to the demands of a relatively underdeveloped legal and business market. Without process control, headquarters may be at risk of losing their dominance over subsidiaries as a result of subsidiaries' access to local markets; however, we do not mean that they would give up all control mechanisms. Instead, for instance, a headquarters might change to the use of output controls. Further, the choice of control mechanism would likely be based on various carefully considered trade-offs between risks and returns (Luo, 2001). If returns from local markets are to be realized, a headquarters should opt for the lessening of process control.

The second contribution of this study indicates that in addition to the commitment of internal resources (either from headquarters or subsidiaries), the utilization of external resources from partners must also be considered in an MNC's selection of control mechanisms. As suggested by the resource dependence perspective, our findings reveal that a subsidiary's technological resource commitment tends to decrease the headquarters' process control, which in turn raises the subsidiary's willingness to contribute its resources. In a host country, when subsidiaries have sufficient technological resources to function well within the local supply chain to improve the existing products of their headquarters, they may earn the mandate from the headquarters to coordinate with local suppliers or customers with autonomy (Birkinshaw, 1996). Accordingly, subsidiaries' technological resources may cause headquarters to reduce their use of process control (Lee et al., 2020).

The same rationale may be used to explain the case of a headquarters' technological resource commitment, which leads to a higher degree of process control. Thus, when a headquarters contribute technological resources to a subsidiary located in China, it must be careful to safeguard its knowledge. Based on the assumption that partners' interests are fairly well aligned with those of subsidiaries, we further explain why the commitment of technological resources by partners induces a lesser degree of process control. One possible reason for this may be that partners, whether in a joint venture or simply possessing technological expertise, may bring valuable interpersonal or organizational networks into the development of subsidiaries (Liu and Chen, 2012). Such networks may act as vehicles for the transmission of new ideas, the initiation of other collaborative relationships, and the mitigation of any undesirable influence that the host government may bring to bear (Luo, 2001). If the possibility exists that these benefits may accrue to overseas firms, headquarters should grant subsidiaries the autonomy to interact with local partners. Therefore, partners' technological resources play a significant role in influencing the use of process control. Overall, our results strongly support our hypotheses.

Implications and conclusion

Our results have several theoretical and managerial implications. First, the existing literature has largely focused on the possession of equity in a subsidiary as the primary indicator of a headquarters' control over that subsidiary (Anderson and Gatignon, 1986). Our study examines key factors influencing MNCs' process control, which have been somewhat ignored in the literature. Our findings of this research fill the gap in the literature. Second, we integrate agency theory and resource dependence theory to investigate MNCs' process control in the international context. Agency theory is generally more concerned with inconsistent goals and information asymmetry between headquarters and subsidiaries but less concerned with resource contributory roles, a concept associated with resource dependence. Our results reveal that Taiwanese MNCs from NIEs tend to choose control mechanisms that fit their technological resources and FDI motivations in China, an emerging economy under an institutional environment characterized by fast economic growth but very different political and economic settings (Luo, 2003; Kaufmann and Roessing, 2005). Third, this study provides insights that shed light on the research of MNCs' process control and suggest managerial implications that require MNCs to revisit their control mechanisms in order to achieve business growth. A better understanding of the FDI motivations and the implications of resource commitment can help HQ managers choose the most effective control mechanisms. HQ managers of NIE multinationals have to not only adjust control mechanisms according to their FDI motivations but also deal properly with the interests of resource contributors in order to sustain economic rewards while limiting risks.

By focusing on agency theory and the resource dependence perspective, our study is clearly one of the few studies to explore how the FDI motivation and resource commitment affect headquarters' process control over subsidiaries. Our findings support the argument that a headquarters will use a higher level of process control to manage its subsidiary in a host country when the primary motivation for setting up the subsidiary is resource-seeking or due to technological resource commitment by the headquarters. Also, a headquarters will use a lower level of process control to manage its subsidiary in a host country when the primary motivation for setting up the subsidiary is market-seeking or due to technological resource commitment by the subsidiary or its local partner(s).

Consequently, entering an emerging economy with inefficient or incomplete markets is a challenge for MNCs from NIEs, since it may be related to high levels of information asymmetry associated with underdeveloped intellectual capital and business environments (Wright et al., 2005). Echoing previous studies emphasizing that the international strategies of MNCs from NIEs are different from those of MNCs from developed economies (Filatotchev et al., 2007; Makino et al., 2002), our evidence indicates that the control mechanisms of MNCs from NIEs

Table 3 Regression analysis for process controls.

	Model 1	Model 2	Model 3	Model 4
Control variables				
Msize	0.07 (0.09)*	0.05 (0.20)	0.06 (0.11)	0.05 (0.21)
MR&D	0.05 (0.18)	0.04 (0.20)	0.04 (0.29)	0.03 (0.33)
Emode	0.18 (0.00)***	0.18 (0.00)***	0.15 (0.00)***	0.15 (0.00)***
SFAII	−0.01 (0.98)	−0.01 (0.82)	−0.01 (0.73)	−0.02 (0.56)
GRIM	0.03 (0.27)	0.03 (0.41)	0.03 (0.31)	0.02 (0.45)
GRE	0.08 (0.00)***	0.08 (0.01)**	0.07 (0.01)**	0.07 (0.01)**
DSCBP	0.01 (0.97)	0.01 (0.83)	0.01 (0.67)	0.02 (0.61)
ILG	0.08 (0.02)**	0.07 (0.02)**	0.06 (0.06)*	0.06 (0.08)*
ILI	0.01 (0.80)	0.01 (0.91)	0.01 (0.69)	0.01 (0.78)
NQETM	−0.01 (0.80)	−0.01 (0.80)	−0.02 (0.61)	−0.02 (0.61)
MAsset	−0.03 (0.53)	0.01 (0.93)	−0.02 (0.65)	0.01 (0.91)
Sexp	−0.14 (0.00)***	−0.15 (0.00)***	−0.12 (0.00)***	−0.13 (0.00)***
UHCLF	−0.06 (0.06)*	−0.05 (0.09)*	−0.04 (0.15)	−0.04 (0.16)
Mlexp	0.05 (0.28)	0.03 (0.49)	0.03 (0.45)	0.02 (0.68)
ISG	−0.02 (0.65)	−0.02 (0.71)	0.01 (0.96)	0.01 (0.89)
MM	−0.17 (0.00)***	−0.16 (0.00)***	−0.16 (0.00)***	−0.15 (0.00)***
CP	−0.09 (0.00)***	−0.08 (0.01)**	−0.01 (0.00)***	−0.08 (0.01)**
FTO	−0.07 (0.03)**	−0.08 (0.03)**	−0.06 (0.06)*	−0.07 (0.05)*
Independent variables				
Resource (H1)		0.08 (0.00)***		0.09 (0.00)***
Market (H2)		−0.12 (0.00)***		−0.09 (0.00)***
Htrc (H3)			0.16 (0.00)***	0.15 (0.00)***
Strc (H4)			−0.14 (0.00)***	−0.15 (0.00)***
Ptrc (H5)			−0.11 (0.00)***	−0.10 (0.00)***
F-value	8.17***	8.51***	10.33***	10.28***
R^2	0.13	0.15	0.18	0.19
Adjusted R^2	0.11	0.13	0.16	0.17
Δ Adjusted R^2		0.02	0.05	0.06
Hierarchical *F*-value		10.18***	20.42***	18.99***

Standardized regression coefficients (β) with *if $p < 0.05$; **if $p < 0.01$; ***if $p < 0.001$.
Msize multinational corporations' size, *Mlexp* multinational corporations' international experience, *MR&D* multinational corporations' R&D expenses, *Emode* entry mode, *SFAII* subsidiaries' fixed asset investment intensity, *Sexp* subsidiaries' experience, *ISG* importance of subsidiary in group, *GRIM* government restrictions on the ratio of imports and exports, *GRE* government restrictions on equity, *DSCBP* differences in social customs and business practices, *ILG* inefficiency of the local government, *ILI* insufficient local infrastructure, *NQETM* non-availability of qualified expertise and technological mechanics, *UHCLF* uncertainty of home country legal framework, *MM* metal and machinery, *CP* chemicals and plastics, *FTO* food, textile and others, *IE* information and electronics, *Resource* resource-seeking motivation, *Market* market-seeking motivation, *Htrc* headquarters' technological resource commitment, *Strc* subsidiary's technological resource commitment, *Ptrc* partners' technological resource commitment.

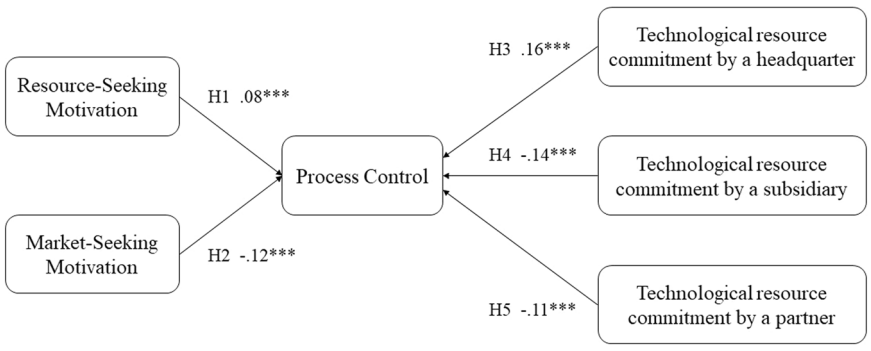

Fig. 2 Empirical results. *Note*: Standardized regression coefficients (β) with *if $p < 0.05$; ** if $p < 0.01$; *** if $p < 0.001$.

entering emerging markets are a bit different, especially with respect to the FDI motivations of headquarters. We hope that our findings will motivate others to extend this line of research.

In this study, there are several research limitations that provide some directions for future research. First, it should be noted that this study uses an empirical setting aimed at subsidiaries of Taiwan-based MNCs doing business in China (i.e., headquarters were located in Taiwan, and subsidiaries were located in China); thus, our findings may not be representative of other emerging markets or transitional economies. Also, caution should be exercised in generalizing and interpreting the relationships among variables and the critical levels derived in this study since our research setting is a case of constant cultural distance in the HQ-Sub relationship in terms of the host and home countries. Second, this study deals primarily with headquarters' motivations for investing in emerging economic regions. In the future, researchers may wish to incorporate data regarding the motivations for investment in developed countries or explore subsidiaries' motivations in emerging markets (Kostova et al., 2018; Lovett et al., 2009). Third, we examined process control as a dependent variable, without the inclusion of outcome control or other variables. Future studies incorporating process control,

output control, and other variables in the same framework may offer further insights into this issue (Lovett et al., 2009). Fourth, although we have highlighted the impact of technological resources, a further examination of resource transfer and leverage processes would provide valuable information regarding their respective impacts on control mechanisms. Fifth, a headquarters' motivations may be related to its positioning of subsidiary roles; thus, the relationship between control mechanisms and subsidiary roles also deserves to be explored (Šalčiuvienė et al., 2008) in future research. Sixth, since our study examines manufacturing companies only, we feel that a future study with the inclusion of service industries would provide widely applicable results. Finally, we are unable to include variables such as sales and financial performance in our study due to the nature of our secondary data. It could have been helpful to include performance measures in our models and avoid the time-lag bias if the longitudinal data is available.

Data availability

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Received: 17 July 2022; Accepted: 27 June 2023;
Published online: 20 July 2023

Notes

1 Technological resource commitment refers to the key resource commitment in this research. With significant advancements in technology, many MNCs now view it as a key niche (i.e., A.I., smartphones, automotive platform solutions, and 2-nm production) (TSMC, 2023).

2 Newly industrialized economy is defined as a country whose level of economic development ranks it between emerging and developed characteristics (Yang and Mohammad, 2023). Wokutch and Singal (2023) rank the order (from most developed to less developed): developed country (i.e., western firms) → newly industrialized economy (i.e., Taiwan) → emerging economy (i.e., China), during 20th century to 21st century.

3 The inflection point of the year 2003 was a turning point for the global economy (World Bank, 2004), as it marked the end of the global recovery from the 2001 recession and the start of a new phase of slower growth. This slower growth was attributed to factors such as rising oil prices, geopolitical tensions, and trade imbalances. World Bank (2004) also notes that emerging market economies, particularly in Asia, were driving global growth and becoming increasingly integrated into the global economy.

References

Agnihotri A, Bhattacharya S, Yannopoulou N et al. (2022) Foreign market entry modes for servitization under diverse macroenvironmental conditions: taxonomy and propositions. Int Market Rev. https://doi.org/10.1108/IMR-09-2021-0287

Aiken LS, West SG (1991) Multiple regression: testing and interpreting interactions. Sage Publications Ltd, Newbury Park

Albertoni F, Elia S, Piscitello L (2019) Inertial vs. mindful repetition of previous entry mode choices: do firms always learn from experience? J Bus Res 103:530–546

Amankwah-Amoah J, Adomako S, Danquah JK et al. (2022) Foreign market knowledge, entry mode choice and SME international performance in an emerging market. J Int Manag 28. https://doi.org/10.1016/j.intman.2022.100955

Anderson E, Gatignon H (1986) Modes of foreign entry: a transaction cost analysis and propositions. J Int Bus Stud 17(3):1–26

Bartlett CA (1986) Building and managing the transnational: the new organizational challenge. In: Porter ME (ed) Competition in global industries. Harvard Business School Press, Boston, pp. 367–401

Birkinshaw J (1996) How multinational subsidiary mandates are gained and lost. J Int Bus Stud 27(3):467–498

Birkinshaw J, Hood N (1998) Multinational subsidiary evolution: capability and charter change in foreign-owned subsidiary companies. Acad Manage Rev 23(4):773–795

Brouthers KD, Hennart JF (2007) Boundaries of the firm: insights from international entry mode research. J Manage 33(3):395–425

Brown JR, Dev CS, Zhou Z (2003) Broadening the foreign market entry mode decision: separating ownership and control. J Int Bus Stud 34(5):473–488

Buckley PJ, Casson M (1976) The future of multinational enterprises. Macmillan, London

Chatzopoulou EC, Dimitratos P, Lioukas S (2021) Agency controls and subsidiary strategic initiatives: the mediating role of subsidiary autonomy. Int Bus Rev. https://doi.org/10.1016/j.ibusrev.2021.101807

Chen SFS, Hennart JF (2002) Japanese investors' choice of joint venture versus wholly-owned subsidiaries in the US: the role of market barriers and firm capabilities. J Int Bus Stud 33(1):1–18

DHL GCI (2022) Global Connectedness Index. https://www.dhl.com/global-en/delivered/globalization/global-connectedness-index.html Accessed 10 Jan 2023

Doz Yves, Prahalad CK (1984) Patterns of strategic control within multinational corporations. J Int Bus Stud 15(2):55–72

Duanmu JL, Lawton T (2021) Foreign buyout of international equity joint ventures in China: when does performance improve?. J World Bus 56. https://doi.org/10.1016/j.jwb.2021.101243

Dunning JH, Lundan SM (1993) Multinational enterprises and the global economy. Edward Elgar Publishing, Cheltenham

Edwards R, Ahmad A, Moss S (2002) Subsidiary autonomy: the case of multinational subsidiaries in Malaysia. J Int Bus Stud 33(1):183–191

Egelhoff WG (1984) Patterns of control in U.S., UK, and European multinational corporations. J Int Bus Stud 15(2):73–83

Eisenhardt KM (1989) Agency theory: an assessment and review. Acad Manage Rev 14(1):57–74

Elia S, Massini S, Narula R (2019) Disintegration, modularity and entry mode choice: mirroring technical and organizational architectures in business functions offshoring. J Bus Res 103:417–431

Fazi T (2023) The deglobalization we need. Compact Mag. https://compactmag.com/article/the-deglobalization-we-need. Accessed 5 Jan 2023

Filatotchev I, Strange R, Piesse J et al. (2007) FDI by firms from newly industrialized economies in emerging markets corporate governance, entry mode and location. J Int Bus Stud 38(4):556–572

Fox Business (2023) House passes bipartisan bill to revoke China's 'developing country' status. https://www.foxbusiness.com/politics/house-passes-bipartisan-bill-revoke-chinas-developing-country-status. Accessed 27 Mar 2023

Gencturk EF, Aulakh PS (1995) The use of process and output controls in foreign markets. J Int Bus Stud 26(4):755–786

Gooch E, Goethe S, Sobrepena N et al. (2022) Measuring competition between the great powers across Africa and Asia using a measure of relative dispersion in media coverage bias. Humanit Soc Sci Commun 9(1):1–14

Hao Y (2023) The dynamic relationship between trade openness, foreign direct investment, capital formation, and industrial economic growth in China: new evidence from ARDL bounds testing approach. Humanit Soc Sci Commun 10(1):1–11

Hennart JF (1991) Control in multinational firms: the role of price and hierarchy. Manag Int Rev 31(1):71–96

Jarillo JC, Martínez JI (1990) Different roles for subsidiaries: the case of multinational corporations in Spain. Strateg Manage J 11(7):501–512

Jensen MC, Meckling WH (1976) Theory of the firm: managerial behavior, agency costs, and ownership structure. J Financ Econ 3(4):305–360

Kaufmann L, Roessing S (2005) Managing conflict of interests between headquarters and their subsidiaries regarding technology transfer to emerging markets—a framework. J World Bus 40(3):235–253

Kostova T, Marano V, Tallman S (2016) Headquarters-subsidiary relationships in MNCs: fifty years of evolving research. J World Bus 51(1):235–253

Kostova T, Nell PC, Hoenen AK (2018) Understanding agency problems in headquarters-subsidiary relationships in multinational corporations: a contextualized model. J Manage 44(7):2611–2637

Lecraw DJ (1984) Bargaining power, ownership, and profitability of transnational corporations in developing countries. J Int Bus Stud 15(1):27–43

Lecraw DJ (1993) Outward direct investment by Indonesian firms: motivation and effects. J Int Bus Stud 24(3):589–600

Lee JY, Jiménez A, Bhandari KR (2020) Subsidiary roles and dual knowledge flows between MNE subsidiaries and headquarters: the moderating effects of organizational governance types. J Bus Res 108:188–200

Li A, Burmester B, Zámborský P (2020) Subnational differences and entry mode performance: multinationals in east and west China. J Manage Organ 26(4):426–444

Li W, Guo B, Xu G (2017) How do linking, leveraging and learning capabilities influence the entry mode choice for multinational firms from emerging markets? Balt J Manag 12(2):171–193

Li Y, Zhang B, Fan D et al. (2021) Digital media, control of corruption, and emerging multinational enterprise's FDI entry mode choice. J Bus Res 130(10):247–259

Lin WT (2019) Market distance and insider-ownership strategies: a resource-dependence perspective. Manage Decis 57(11):2958–2977
Liu MC, Chen SH (2012) MNCs' offshore R&D networks in host country's regional innovation system: the case of Taiwan-based firms in China. Res Policy 41(6):1107–1120
Liu Y, Li X, Zhu X et al. (2023) The theoretical systems of OFDI location determinants in global north and global south economies. Humanit Soc Sci Commun 10(1):1–13
Lovett SR, Pérez-Nordtvedt L, Rasheed AA (2009) Parental control: a study of U.S. subsidiaries in Mexico. Int Bus Rev 18(5):481–493
Lu JW, Li W, Wu A et al. (2018) Political hazards and entry modes of Chinese investments in Africa. Asia Pac J Manag 35(2):39–61
Luo Y (2001) Determinants of entry in an emerging economy: a multilevel approach. J Manage Stud 38(3):443–472
Luo Y (2003) Market-seeking MNEs in an emerging market: how parent-subsidiary link shape overseas success. J Int Bus Stud 34(3):290–309
Luo Y, Shenkar O, Nyaw MK (2001) A dual parent perspective on control and performance in international joint venture: lessons from a developing economy. J Int Bus Stud 32(1):41–58
Ma J, Yang J, Song Y (2021) The contingent effect of political ties on post-entry performance. A three-way interaction of political ties, entry mode, and industry restriction. Manage Decis 59(1):104–117
Makino S, Lau CM, Yeh RS (2002) Asset-exploitation versus asset-seeking: implications for location choice of foreign direct investment from newly industrialized economies. J Int Bus Stud 33(3):403–421
Mas-Ruiz FJ, Ruiz-Conde E, Calderón-Martínez A (2018) Strategic group influence on entry mode choices in foreign markets. Int Bus Rev 27(6):1259–1269
Miller SR, Calantone R, Indro DC et al (2009) The effects of strategies on the management control-performance relationship in Sino joint ventures. In: Cheng J, Maitland E, Nicholas S (eds) Managing, subsidiary dynamics: headquarters role, capability development, and China strategy. Advances in international management, vol 22. Emerald Group Publishing Limited, Bingley, pp. 189–217
Mjoen H, Tallman S (1997) Control and performance in international joint ventures. Organ Sci 8(3):257–274
Moalla E, Mayrhofer U (2020) How does distance affect market entry mode choice? Evidence from French companies. Eur Manag J 38(1):135–145
MOEA (Ministry of Economic Affairs) (2002) Survey of foreign investment of Taiwanese manufacturing industries. Ministry of Economic Affairs, Taiwan
Nachum L, Zaheer S (2005) The persistence of distance? The impact of technology on MNE motivations for foreign investment. Strateg Manag J 26(8):747–767
Nobel R, Birkinshaw J (1998) Innovation in multinational corporations: control and communication patterns in international R&D operations. Strateg Manag J 19(5):479–496
O'Donnell SW (2000) Managing foreign subsidiaries: agents of headquarters, or an interdependent network. Strateg Manag J 21(5):525–548
Oliver RL, Anderson E (1994) An empirical test of the consequences of behavior- and outcome-based sales control systems. J Mark 58(4):53–67
Ouchi WG (1977) The relationship between organizational structure and control. Admin Sci Q 22(1):95–112
Pugliese A, Minichilli A, Zattoni A (2014) Integrating agency and resource dependence theory: firm profitability, industry regulation, and board task performance. J Bus Res 67(6):1189–1200
Ripollés M, Blesa A (2017) Entry mode choices in the international new ventures context. A study from different theoretical perspectives. Int Entrep Manag J 13:465–485
Šalčiuvienė L, Auruškevičienė V, Vanagė J (2008) Factors determining creation of competitive advantages in the subsidiaries of international business. Transform Bus Econ 7(3):31–46
Sarkodie SA, Ahmed MY, Owusu PA (2022) Global adaptation readiness and income mitigate sectoral climate change vulnerabilities. Humanit Soc Sci Commun 9(1):1–17
Schwens C, Zapkau FB, Brouthers KD et al. (2018) Limits to international entry mode learning in SMEs. J Int Bus Stud 49(1):809–831
Stendahl E, Schriber S, Tippmann E (2021) Control changes in multinational corporations: adjusting control approaches in practice. J Int Bus Stud 52(3):409–431
Tse CH, Yim CKB, Yin E et al. (2021) R&D activities and innovation performance of MNE subsidiaries: the moderating effects of government support and entry mode. Technol Forecast Soc. https://doi.org/10.1016/j.techfore.2021.120603
Tse YK, Zhang M, Tan KH et al. (2019) Managing quality risk in supply chain to drive firm's performance: the roles of control mechanisms. J Bus Res 97:291–303
TSMC (2023) Technology symposium. https://www.tsmc.com/static/english/campaign/Symposium2023/index.htm. Accessed 10 Apr 2023
United Nations Conference on Trade and Development (UNCTAD) (2019) World investment report. United Nations Conference on Trade and Development (UNCTAD), United Nations, New York
Valorinta M, Schildt H, Lamberg JA (2011) Path dependence of power relations, path-breaking change and technological adaptation. Ind Innov 18(8):765–790
Van Hoesel R (1999) New multinational enterprises from Korea and Taiwan: beyond export-led growth. Routledge, New York
Wan C, Sousa CMP, Lengler J et al. (2023) Entry mode choice: a meta-analysis of antecedents and outcomes. Manag Int Rev 63:193–246
Wang Y, Xie Z, Xie W et al. (2019) Technological capabilities, political connections and entry mode choices of EMNEs overseas R&D investments. Int J Technol Manag 80(1–2):149–175
Wokutch RE, Singal M (2023) Newly industrialized country. Britannica. https://www.britannica.com/topic/newly-industrialized-country. Accessed 20 Mar 2023
World Bank (2004) World Bank annual report 2004: year in review. https://documents.worldbank.org/en/publication/documents-reports/documentdetail/335261468762927443/year-in-review. Accessed 1 Jul 2010
Wright M, Filatotchev I, Hoskisson RE et al. (2005) Strategic research in emerging economies: challenging the conventional wisdom. J Manag Stud 42(1):1–33
Yan A, Gray B (2001) Antecedents and effects of parent control in international joint ventures. J Manag Stud 38(3):393–416
Yan Y, Child J (2004a) Investors' resources and management participation in international joint ventures: a control perspective. Asia Pac J Manag 21(3):287–304
Yan Y, Child J (2004b) Investors' resource commitments and information reporting systems: control in international joint ventures. J Bus Res 57(4):361–371
Yang J, Mohammad S (2023) Is the cure worse than the disease? The effect of emerging market MNEs on host country corruption. Int Bus Rev 32(3). https://doi.org/10.1016/j.ibusrev.2022.102066
Yu CMJ, Wong HC, Chiao YC (2006) Local linkages and their effects on headquarters' use of process controls. J Bus Res 59(12):1239–1247

Acknowledgements

This research has been supported by the National Science and Technology Council (NSC-96-2416-H-005-017, Taiwan). An earlier version of the paper was presented at the Academy of International Business Southeast Asia Regional Conference (AIBSEAR) in Cebu, Philippines, in 2019.

Competing interests

The authors declare no competing interests.

Ethical approval

This article does not contain any studies with human participants performed by any of the authors.

Informed consent

This article does not contain any studies with human participants performed by any of the authors.

Additional information

Correspondence and requests for materials should be addressed to Yu-Ching Chiao.

Reprints and permission information is available at http://www.nature.com/reprints

Publisher's note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.