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Techno-nationalism and capability development in the global pharmaceuticals industry, 1918–1970

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Abstract
Techno-nationalism intensifies deglobalisation and so presents new risks in international business, with government policy increasing multinational corporation (MNC) costs through targeting their technology inflows and outflows in various ways. However, recent scholarship in international business has focused exclusively on the current geopolitical tensions between the US and China. We adopt a longer-term perspective that permits us to offer a revised definition of techno-nationalism less embedded in the present-day context. We then review three episodes of historical techno-nationalism by the U.S. and U.K. governments targeting the acquisition of pharmaceuticals technological capabilities from the then-technological leaders between 1918 and 1970. This review suggests that the success of techno-nationalist policies was less associated with the absolute level of costs imposed on MNCs and more associated with: the absorptive capacities of the host economies' domestic industries; the ease with which the targeted MNCs were able to develop mitigation strategies; and, our main contribution, the different mechanisms used and targets focused on by governments. We develop a typology of successful techno-nationalist policies from this historic survey to highlight that government policies might vary between those that differentiate between either technology-push or demand-pull mechanisms and those that focus on either firm-based or location-based targets.

Keywords Techno-nationalism · Pharmaceuticals · History of international business · Business history · Historical methods

Introduction

Recent developments in global economic relations have revealed limits to the post-1970 liberal world trading order. The beginnings of deglobalization and the emergence of competing geopolitical powers have caused multinational corporations (MNCs) to recalibrate their global value chains along the lines of geopolitical blocs as the increasing costs associated with "bifurcated governance" become apparent (Petricevic & Teece, 2019), some even having to accommodate attempts by rival powers to gain access to their strategically important technologies (Bhaumik et al., 2024; Buckley, 2023; Luo & van Assche, 2023; Witt, 2019a). Some international business (IB) scholars have begun to draw on the concept of techno-nationalism, positing that this recent trend in deglobalization represents something different from the policies of economic nationalism seen in the past (Jones & Lopes, 2021; Li et al., 2024; Luo, 2022).

The concept of techno-nationalism is far from fully articulated, and there are significant gaps in our understanding of how it can be applied by IB scholars to current situations (Luo & van Assche, 2023). It is obvious that techno-nationalist policies increase the costs to MNCs, and, as governments retaliate, so the costs to MNCs further increase. However, little is currently understood about how MNCs might respond to these higher costs, what might be the threshold before such costs would lead to withdrawal from hostile host economies, and what the range of possible strategies might be for MNCs to mitigate the risks of techno-nationalism. Equally, for scholars of international business policy, there

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is as yet insufficient understanding about which techno-nationalist policies of the challenger country governments might be successful in acquiring technological capabilities from the incumbent technologically leading power (Li et al., 2024).

This paper seeks to provide a brief review of techno-nationalism over the long run to introduce IB researchers to the historical parallels of these recent trends. The literature on the history of international trade disputes is vast, but typically insufficiently precise for the purposes of scholars interested in techno-nationalism today. The paper therefore concentrates on one specific technological pathway in one specific product group—pharmaceuticals—to permit a more analytically focused historical comparison. The pharmaceutical industry over the course of the 20th century was a high-technology industry, whose strategic importance was such that different governments pursued policies which, as we shall see, were very similar to those described as techno-nationalist today. Obviously, there are major differences in the wider contexts facing pharmaceuticals producers in the middle decades of the 20th century and Chinese and American producers of digital technologies today. Despite these differences, the paper aims to enhance our understanding and theorization of techno-nationalism in IB today through this comparison by showing that there was a wide variety of techno-nationalist policies adopted by governments in the past. The next section explores the concept of techno-nationalism as it has become used in IB today, clarifying its key constructs so that they can be applied to earlier periods. Then, after describing our method and data, the paper surveys three episodes where techno-nationalist policies were implemented by the U.S. and British governments attempting to acquire technological capabilities in pharmaceuticals. These had very different outcomes; some episodes were clear failures, whereas others were successful. Because of our focus on a number of case studies within the same technological pathway, these results permit us to develop a typology of successful techno-nationalist policies that varied according to the mechanisms they adopted and to the targets governments focused on to promote the acquisition of key technological capabilities.

Techno-nationalism in theory and history

Rising inequalities in advanced economies led to growing demands for protectionism just as the first globalization wave peaked in 1913. Geopolitical tensions remained elevated from the beginning of World War I until the 1970s, inhibiting international business. These tensions meant that the middle decades of the 20th century were characterised first by a phase of deglobalization in the inter-war years, then by total war, and, finally by "moderated globalisation" under the Bretton Woods regime, rather than the deeper levels of globalisation that began to emerge towards the end of the 20th century (Jones, 2005; Jones & Lopes, 2021; Rodrik, 2011). Business history is thus replete with examples of how host country government nationalist ideals adversely impacted MNCs during this period. For instance, the Communist revolution in Russia led to the expropriation of assets of non-domestic companies. Organizations like Singer, which had built the largest manufacturing facility in Imperial Russia for its sewing machines, withdrew entirely from what was its largest market after 1919 (Carstensen, 1984; Godley, 2006). The Mexican Revolution of 1938 also led to the withdrawal of many U.S. firms. Some MNCs managed to continue operations despite the hostile environment. The British oil major, Mexican Eagle, for example, exploited its non-U.S. credentials in order to curry favour with the new regime (Bud-Frierman et al., 2010; Haber et al., 2003). Similar strategies were pursued by German MNCs in India as the independence movement there placed higher liabilities of the country-of-origin on subsidiaries of British firms during the 1930s and 1940s (Lubinski, 2015). A range of examples of adaptation rather than withdrawal can be seen in the case of United Fruit in Colombia, which sold its land assets and focused on marketing in order to mitigate the risk of expropriation (Bucheli, 2005). Similarly, British MNCs responded to the independence movements in west Africa in the 1960s with a variety of strategies in order to retain their presence: from major public relations programmes, to selling stakes to indigenous interests, to outright bribery (Decker, 2008, 2022a). While the business history literature on MNC responses to geopolitical tensions and the rise of economic nationalism is therefore large, the focus here is on techno-nationalism, an acutely specific variant of economic nationalism.

Techno-nationalism originated in the realist school of political science as a theory outlining the extension of zero-sum Great Power relations to the sphere of international trade (Montresor, 2001; Samuels, 1994), but IB scholars have begun to develop and analyse the concept in novel ways (Luo & van Assche, 2023). Luo defines this "new" techno-nationalism as "an emerging strain of geopolitical thinking and actions that link technological capabilities directly to a country's national security and geopolitical benefits, involves legal and regulatory restrictions or sanctions against selected foreign investors or foreign companies" (2022, p. 551). From a theoretical perspective, techno-nationalism differs from the more general economic nationalism by having three very specific features: (1) the presence of deglobalization and decoupling, (2) the articulation of certain technological capabilities as possessing strategic significance to the nation, and (3) that these technological capabilities are

in some way threatened by the activities of foreign actors (typically governments) (Luo, 2022).[1]

The emergence of this new techno-nationalism is nowadays associated above all with the international rivalry between the U.S. and China, where the Chinese government is seeking to challenge U.S. hegemony through acquiring U.S. technological capabilities in key sectors and the U.S. government is retaliating in response. Both governments have pursued decoupling programs and have restricted the other nation's firms from having easy access to the others' markets and to key technologies. Notably, the U.S. has restricted Chinese firms' access to the tools and technologies needed for the development of advanced microchips, and China has restricted U.S. firms' access to certain critical materials (Lovely & Yan, 2024; Luo & van Assche, 2023; *Financial Times*, 2024). Given that the concept of techno-nationalism is currently being so closely identified with this most recent, specific, episode of geopolitical tensions, the current theory and definition of the concept are likely to be heavily infused with this present-day historical context. It is therefore important to think through what the defining features of techno-nationalism might be and to clarify its foundational constructs so that it can be applied to different historical episodes.

Critical features of "new" techno nationalism identified by Luo (2022) include: decoupling, strategically significant technological capabilities, and the existence of a perceived threat to national interests. Each of these three features needs further theoretical elaboration. The first, decoupling, is important because as deglobalization reduces economic interdependence, the economic returns to co-operation diminish. If the costs of foregoing future trade have been reduced, the relative costs of short-term opportunism are also reduced and zero-sum policies appear more attractive (Luo, 2022, p. 557). While scholars recognise that technological decoupling in practice is highly complex (Dachs et al., 2024; Witt, 2019b), the key construct to this element of techno-nationalism is not decoupling *per se*, but that international relations are dominated by zero-sum thinking, and that this influences government policy toward the national development of technological capabilities (Luo & van Assche, 2023).

That certain technological capabilities are deemed to be strategically significant is the second necessary precondition for techno-nationalism. Here, technological capabilities are more than simply the possession of the ability to produce what is currently a strategically important technology. Rather, what is critical are the research and development capabilities that shape the development of specific technological pathways, thereby ensuring the continuation of national technological leadership. This focuses the concept of techno-nationalism more on national research and development capabilities rather than production (Dachs et al., 2024; Edgerton, 2007). Identification of those technological capabilities deemed to be of strategic significance will, of course, change unpredictably over time. The ability to develop ever more powerful semiconductors was not understood to be strategically important 20 years ago, for example. Conversely, other technological capabilities were earlier thought to be indispensable but subsequent innovations have rendered them near obsolete; consider fermented protein technology in the 1960s, for example (Godley, 2024). Luo mentions that the reason why digital technologies and ICT have become so strategically significant in recent years is because they provide a "foundational infrastructure" for society at large (2022, p. 555). The key feature of the technology under focus within techno-nationalism is, in other words, its importance to some wider system of societal significance. In earlier times, the technologies which provided foundational infrastructures for societies would have been different. For almost all of the 20th century, one such technology was advanced pharmaceuticals because this offered relief to societies from entire classes of previously incurable diseases.

The third element of techno-nationalism is the identification of some sort of threat to national interests in the event that either access to the focal technology is restricted or that the possession of relevant R&D capabilities is threatened. Once again, this feature of the concept of techno-nationalism has two components. First, that under conditions of economic liberalism and globalization, technological capabilities are easily traded and, at least partially, replicated as certain R&D functions are internationalized. By contrast, under conditions of techno-nationalism, they are hoarded. Hegemonic power governments devise policies to restrict rival countries' access to key research capabilities, and rival challenger nations (or blocs) pursue policies to capture them, and so ultimately to acquire technological leadership for their domestic industries. The second component of this feature of techno-nationalism is that the specific articulation of what is in the national interests of a country changes over time. The significance of the threat of withholding access to semiconductors is that we are now living in a digital age: microchips are the passport to digital existence and possess critically important military applications. However, in earlier, pre-digital, times, other technologies were deemed to be of greater importance to the national interest. Furthermore, the identification of what is deemed to be in the national interest is often conflated with national

[1] For completeness' sake, we note that Luo also identifies the ability of national governments to design and implement techno-nationalist policies which are effective beyond their jurisdictions. Given the history of imperialism and post-imperialism over the period under consideration here, this is a particularly complex feature to develop historical parallels for, and so, for the sake of brevity, we omit its consideration.

security concerns; and certainly, much of the rhetoric surrounding U.S. policy today is framed as a response to the growing military threat that the Chinese pose to American interests. Nevertheless, those phenomena that pose threats to a nation's interests are actually better understood as posing threats to a nation's foundational values and ideologies (Luo, 2022, p. 561). These are seen overtly in cases of military threats, but, in principle, it may be the case that economic and/or social interests have been of at least as great a concern in the identification of what is in the national interest at certain points in time. A geopolitical threat to national interests is not identical to a geopolitical threat to national security within the concept of techno-nationalism. Focusing on these more fundamental constructs, we might amend Luo's (2022) definition of new techno-nationalism, quoted above, as: an emerging strain of zero-sum geopolitical thinking and actions that directly relates a country's superiority compared to its rivals to its strength in advanced research and development capabilities for technologies that are foundational to its social well-being.

Currently, there is little in the literature that offers recommendations to MNCs about the responses they may make to different types of techno-nationalist policies (Luo & van Assche, 2023). The dominant theme in the literature is the importance to MNCs of regionalising global value chains in order to mitigate the risks to proprietary intellectual property within one bloc or another (Dachs et al., 2024; Kano et al., 2020). Further, there is also little in the literature that would seek to explore under what conditions a government's techno-nationalist policies are more or less likely to be successful in acquiring technological capabilities from the technologically leading MNCs. Instead, there is a presumption that techno-nationalism imposes varying levels of (not clearly specified) costs on technologically leading MNCs, and that MNCs adapt and pursue strategies to mitigate these costs. In consequence, there is little in the literature to help understand, in the event that geopolitical tensions lead to even more costly environments for international business, "what we should do to cope *if* techno-nationalism, digital decoupling, trade-war, ideological tensions, and deglobalization continue to ensue and become even more profound and enduring. This question could be the biggest question ever in the IB-field and we must draw due attention to it" (Luo, 2022, p. 564).

Exploring what would happen in these even more complex and costly conditions is difficult and demands the development of new theorizing and empirical exploration (Witt, 2019b). In this light, the historical precedent of the post-World War I period of deglobalization and the policies of protectionism and autarchy adopted by several governments of the time becomes highly pertinent to current-day deliberations. At times of great uncertainty, inductive reasoning through historical analogy can be of great value. Historical comparisons cannot provide IB scholars with predictions for future behaviour, but they can offer warnings. This paper therefore focuses on the case study of techno-nationalism and the global pharmaceuticals sector in the period from 1918 up to the beginning of the modern liberal trading order in 1970, surveying specific attempts by governments to acquire and to transfer technological capabilities to their domestic industries.

Historical method and empirical setting

As the international environment has become increasingly hostile to continued globalization, so the field of IB has found itself less well equipped to engage with the transition to deglobalization (Buckley et al., 2017). Drawing from the body of empirical knowledge within the field of business history about previous periods of deglobalization would appear to be an obvious step for IB scholars (Jones, 2005; Jones & Lopes, 2021), and it has become increasingly common for IB scholars to call for more historical approaches (Buckley, 2009, 2021; Cantwell et al., 2010; Jones & Khanna, 2006; Verbeke & Kano, 2015; Verbeke et al., 2018; Welch et al., 2022). Business history, though, provides more than just an under-used evidence base for IB scholars. Historical methods provide a relatively novel yet particularly valuable approach for exploratory theorization because they lead ineluctably to more nuanced interpretations of complex phenomena and impose a brake on more reductionist methods. This is in part because historical methods focus on extracting data from fragmentary archival documents. This, historians claim, provides the additional nuance and context to historical analysis (Bucheli & DeBerge, 2024). This claim is somewhat counter-intuitive; non-historians might imagine, given extreme data scarcity, that source-credulity might be a pervasive weakness for business history research. Historical methods, however, are founded on the rigorous scrutiny of sources: clarifying their provenance, testing their representativeness, and making transparent any potential biases (Kipping et al., 2014). The result is that the discussion by historians of some focal phenomena is more nuanced and sensitive to alternative interpretations than would be common in most IB research. Moreover, with a longitudinal perspective typically covering several decades or more, historical researchers have to accept the consequence of the temporal distance between the focal phenomenon and the researcher, which is that understanding the past must be incomplete because of the different historical contexts. Historical analysis is therefore flawed without the explicit incorporation of changing historical context (Decker, 2022b; Gaddis, 2002; Hamilton & Godley, 2024).

Historical approaches to IB must therefore be pursued carefully. For historical cases to be of any value to current

IB thinking, they must be selected through explicit theoretical sampling, where the historical cases can be properly matched with the current focal phenomena. Earlier cases that display some similarity to the current focal phenomena are nevertheless different, by definition, because they emerged in a different historical context. So, while historical methods must incorporate historical context into the analysis, in order for the results to generate meaningful insights for the IB field, appropriate research strategies should be adopted to permit greater analytical precision (Buckley, 2021). The outcome is a method that lends itself to contextualised explanation (Godley et al., 2025; Welch et al., 2022).

There are several recent exemplar contributions to IB by business historians. For instance, several papers have explored the limits of corporate headquarters control over subsidiaries under differing conditions. Da Silva Lopes et al. (2019) showed how a certain category of early 20th-century British MNCs (called free-standing companies) denuded central control by transferring all corporate headquarters functions to the overseas subsidiaries apart from formal company registration and reporting to shareholders. Jones and Lubinski (2012) showed how German Jewish-owned MNCs both transferred assets to overseas subsidiaries and formally divested control during the 1930s as the Nazi government increasingly discriminated against Jews in Germany. Godley et al. (2025) showed how subsidiary autonomy has led to institutional innovation in the internationalization of R&D in the 1950s and 1960s. Other scholars have highlighted how MNCs have responded to complex market environments by developing non-market strategies (Bucheli & DeBerge, 2024), often through legitimacy building with key host country stakeholders (Bucheli, 2005; Bucheli et al., 2023).[2]

The focal phenomenon in this paper is techno-nationalism, particularly its recent more hostile manifestation. As we have already seen, it possesses at least three core elements, which must therefore be replicated in any historical comparison: that it emerges in an environment of decoupling and is associated with zero-sum policy-making; that it has identified the ownership of complex, scarce research capabilities within a nation, which are important to the national interests because they provide some sort of societal "foundational infrastructure"; and that there is a strong sense among policymakers that the national interests are sufficiently under threat from rivals to justify some intervention either to protect or to capture this near-unique asset.

The selected empirical setting for this historical exploration of the impact of techno-nationalism is the global pharmaceuticals industry from 1918 to 1970. The dominant producer of scientifically advanced pharmaceuticals technology in the years before World War I was Germany. Germany had created a system for developing and exploiting new pharmaceuticals technologies based on deep collaborations among its leading university scientists and large pharmaceuticals manufacturers. In all markets around the world, German products were totally dominant. At the same time Imperial Germany as a nation also emerged as the leading European contender to the political dominance of the British Empire, with geopolitical tension increasing in the years before 1914. While the outcome of World War I reduced the German geopolitical challenge during the 1920s and led to the emergence of a more multilateral world order, the impact of the financial crisis after 1929 led to increased nationalism and protectionism in much of the world. The Nazi seizure of power in Germany in 1933 led to the re-emergence of geopolitical tension with the establishment of the German Third Reich. The German pharmaceuticals industry remained dominant throughout.

Despite the creation of the first institutions of what was later to become the world's liberal trading order in the late 1940s and early 1950s, Germany's defeat in World War II failed to usher in an end to geopolitical tensions with the advent of the Cold War and the diminution of British global influence. The sustained focus on global pharmaceuticals during this period, and on the repeated attempts to acquire technological capabilities by challenger governments, produces a series of episodes, each of which conform with both Luo's definition of "new" techno-nationalism and our amended version. What follows is a (necessarily brief) survey of several episodes of techno-nationalism within the global pharmaceuticals industry during these years, identifying why some of these challenger country techno-nationalistic policies failed and why some succeeded.

Three historical episodes of techno-nationalism in global pharmaceuticals

Episode 1. Weaponizing trade: Tariff barriers and expropriation policies to reduce the threat of German dominance, 1918–1939

The German synthetic chemicals industry had acquired global leadership in the years before 1914. Its leading chemicals companies, Bayer, BASF and Hoechst, dominated global dyestuffs. The modern pharmaceuticals industry was spawned from the realization that some of these synthetic dyes also held therapeutic properties; by 1914 novel treatments for syphilis and analgesia had emerged from the growing research agendas of these giant German chemicals firms (Godley et al., 2019; Lesch, 2007; Liebenau, 1988; Steen,

[2] See also Decker (2022b) and Niittymies et al. (2022) for other recent contributions, which build on Rowlinson et al. (2014) and Keulen and Kroeze (2012).

2014). These firms had developed strong collaborative relations with the leading scientists at Germany's top universities, and this model of research collaboration extended to both their own pharmaceuticals divisions and beyond to the traditional fine chemicals businesses, like E. Merck of Darmstadt and Schering (Beer, 1959; Burhop, 2009; Cramer, 2015). The two most important markets for German pharmaceuticals were the U.S. and the U.K., and, up until the early 1900s, German firms focused on meeting demand in these markets via export. Regulatory changes in both these markets (the 1902 Food and Drug Act in the U.S. and the 1907 Patent Act in the U.K.) stimulated foreign direct investment (FDI) by stipulating that all medicines needed to comply with local potency testing and inspection. By 1914, all the leading German pharmaceuticals producers had opened small factories in both the U.S. and the U.K. (Corley, 2003; Godley et al., 2025; Kobrak, 2002).

In contrast, the leading British firms were mostly wholesalers, specializing in sourcing specialist plants and barks for pharmacists to then make up into medicines (Corley, 2003). An important exception to this, however, was Burroughs Wellcome & Co., which had pioneered laboratory-based R&D in Britain during the 1890s (Brooks & Buckley, 2024; Church, 2006). American firms, meanwhile, did focus more on manufacturing for end-users, but overwhelmingly as producers of herbal remedies such as laxatives and analgesics; their vigorous promotion of these 'patent medicines' leading to persistent conflict with the American Medical Association and the wider U.S. academic community (Liebenau, 1984). Apart from Wellcome, neither the U.S. nor the U.K. industries were science-based. Outside small laboratories for basic potency testing, there was almost no research undertaken by these British and American firms. Large German pharmaceuticals firms were much more research-intensive, protected their research through strategic patenting, and were typically ten times bigger than their U.S. and U.K. peers (Beer, 1959; Cramer, 2015; Godley et al., 2019; Lesch, 2007, pp. 15–50).

In both the U.S. and the U.K, the blockade on German shipping after 1914 gave rise to a sudden realization of their vulnerability to certain diseases. Syphilis posed one of the biggest threats to the allied armies' fighting strength in the near total absence of advanced medicines for its treatment from Germany, for example (Church & Tansey, 2007, p. 256; Steen, 2014, pp. 152–156). Both the British and American governments responded to what was seen as an intolerable situation by privileging indigenous pharmaceuticals producers, expropriating German producers' intellectual and physical property, and then selling these off to domestic interests (Corley, 2003; Godley et al., 2025; Wilkins, 2004). This was an enormous shock to German business owners (Jones & Lubinski, 2012; Steen, 2014, pp. 244–5). Worse was to follow. In response to post-war demands to punish Germany, both the American and British governments identified the potential for German firms to recapture their pharmaceuticals markets as a national threat. Both governments believed that having acquired ownership of German patents, plant and machinery, indigenous producers would be able to supply domestic needs. The prospect of German producers re-entering these markets and undermining the nascent British and American producers led to the imposition of punitive tariffs (Foreman Peck, 1994, p. 9; Steen, 2014, p. 148).

Having been stung for the loss of their assets during the war, German producers were very reluctant to pursue FDI after the war had ended (Schroeter, 1988). Only Schering swallowed its losses and established new subsidiaries in both countries (Kobrak, 2002, pp. 151–6). The rest tried a variety of strategies to re-enter these markets. Bayer and Hoechst formed joint ventures with indigenous firms (Godley et al., 2019; Steen, 2014, pp. 244–8; Wilkins, 2004). Others entered via stealth, using secret deals, concealing ownership of subsidiaries via naturalized family members, former employees, or trusted friends, in the firm expectation that the true ownership of these assets could formally be re-established later (Jones & Lubinski, 2012; Kobrak & Wustenhagen, 2006, p. 415). This strategy, called "cloaking," of hiding German assets in the U.S. and U.K. led to considerable complications. The former U.S. subsidiary of the German firm E. Merck had been reacquired by its former manager and family member, the now naturalized U.S. citizen George Merck, on condition that an Alien Property Custodian-mandated Trust would oversee its formal separation from its former German parent and its continuing "de-Germanization". Despite this, the German Merck secretly transferred manufacturing and research technologies to the U.S. Merck as if it was still its subsidiary, transforming the research capabilities of American Merck almost at a stroke (Godley et al., 2019).

The net result of higher tariffs in the inter-war years was for German pharmaceuticals exports to decline precipitously to the U.S. and U.K. (Foreman Peck, 1994, Table 4, p. 9; Godley et al., 2019). The "cloaked" FDI failed to compensate the German firms for their loss of access to these key export markets. However, it was not the case that British and American firms were able to exploit German technologies—newly acquired through government intervention—in their protected domestic markets. The research, development, and manufacturing competencies of almost all the leading U.S. and U.K. pharmaceuticals firms were simply insufficiently advanced to be able to develop their equivalent production. There were a tiny number of exceptions; Sterling and Abbott built profitable businesses based on German patented analgesics and anaesthetics in the U.S., for example (Abbott, 1987, p. 75; Mahoney, 1959). Other firms were, however, either unable to manufacture the products (Kobrak, 1996, p. 16) or unwilling to take the risk (Meyer, 1965, p. 10). In the

U.K., while several companies were successful in replicating the manufacture of German pharmaceuticals during the war, on the resumption of peace only two, May & Baker and Wellcome, continued to produce their versions of German-invented products (Slinn, 1984, pp. 91–3).

Both the U.S. and U.K. governments adopted what would be understood today as extreme techno-nationalist policies, with the aim of forcing the transfer of German technological capabilities to indigenous companies by shutting German MNCs and their products out. However, very few British and American companies possessed the absorptive capacity (Cohen & Levinthal, 1990) necessary to take advantage of heavily subsidized patents, expropriated assets and machinery, and tariff walls. The policies implemented by both challenger governments to "de-Germanize" pharmaceuticals therefore failed, even in such protected markets. By the end of the inter-war period, Germany's Revealed Technological Advantage in global pharmaceuticals was even greater than it had been in 1914 (Cantwell, 1991). Germany's dominance of advanced pharmaceuticals had grown over the period.

Episode 2. Weaponizing wartime demand. The Penicillin Race in World War II and the transformation of the U.S. pharmaceutical industry

The onset of World War II brought similar dilemmas to the U.S. and U.K. governments as those they had faced in World War I, with the threat of restrictions to the supply of key German medicines. By the late 1930s, the pharmaceuticals sector was in the early stages of what promised to be a revolution in treating infectious diseases. The initial breakthrough had come in Germany, when Bayer published the results of the clinical trials of its first sulphonamide in 1935, demonstrating the remarkable finding that derivative compounds from some coal tar dyes had anti-microbial properties; they could fight infections (Lesch, 2007). The result sent shock waves around the world's medical communities. Many pharmaceutical companies tried to find out if similar results could be obtained from slightly different compounds (Church & Tansey, 2007, p. 356; Godley & Williams, 2009; Lesch, 2007, pp. 197–203; Mahoney, 1959; Meyer, 1965; Slinn, 1984).

In the U.K., scientists investigating other possible sources of anti-infective therapies returned to Alexander Fleming's near-forgotten discovery of *Penicillium* moulds' anti-microbial properties. In 1941, they made the startling discovery that penicillin was an even more powerful antibiotic than sulfa drugs (Liebenau, 1987). Researchers in Germany, Czechoslovakia, France and the Netherlands (all then under German control) were also experimenting with penicillin (Bud, 2007, pp. 76–81; Bud, 2011; Quirke, 2004, pp. 78–80). The story of the international race to manufacture penicillin at scale is well known; scientists, pharmaceuticals manufacturers, politicians and generals all understood its potential benefit to the war goals (Bud, 2007; Liebenau, 1987). Among the Allies, there were two similar attempts, one in the U.K. and one in the U.S., to convert what was a very fragile mould into a medicine that could be sent thousands of miles to treat thousands of wounded soldiers. For the purposes of this paper, we focus on the role of U.S. and U.K. government policy in these two races for penicillin production, and to identify how the U.S. government was able to support its pharmaceutical industry more successfully than was the case in the U.K. in the critical years from 1941 to 1945. Success in techno-nationalist policies allowed the U.S. firms to wrest technological leadership from the German companies in the late 1940s.

United Kingdom

The British pharmaceuticals industry in the run-up to World War II still had little research expertise and limited manufacturing competences (Bud, 2007, p. 48). The background for most of the industry was in fine chemicals trading and wholesaling. Only a few firms had integrated forwards into any kind of manufacturing. With the notable exception again of Wellcome, even fewer firms developed research capabilities. In the build-up to war, U.K. policymakers had acknowledged the country's vulnerability and approached international (but non-German) suppliers of key medicines. Abbott (U.S.) opened a plant in the U.K. to secure supplies of anaesthetic (Slinn, 1999, p. 8). Ciba (Switzerland), Lilly (U.S.) and Organon (the Netherlands) established small insulin plants in 1938 and 1940 (Godley et al., 2025).

Outside Wellcome, genuine research capabilities among the U.K.'s pharmaceutical firms were limited to just Boots, May & Baker, Glaxo, and the British Drug Houses. These five companies collectively founded the Therapeutic Research Corporation (TRC) in 1942 to pursue collaborative efforts to meet wartime requirements (Davenport-Hines & Slinn, 1992; Liebenau, 1987). The TRC was explicitly an attempt to address the industry's perceived weakness in research. Its main priority was to devise methods to scale up the manufacture of penicillin. The critical technology was fermentation, which has been used since ancient times to produce foods, such as cheese, and beverages, such as beer. However, the process for the fermentation of penicillin was complicated, with sterile conditions essential or yields collapsed. By the end of the war, the consortium was producing enough penicillin to meet the needs of the British military (Davenport-Hines & Slinn, 1992, p. 146). They had benefitted from the direct subsidies offered by the British government. They had coordinated their R&D on manufacturing processes to some extent, and there was growing confidence that they understood the chemical structure

of penicillin (Davenport-Hines & Slinn, 1992; Liebenau, 1987). However, because this was a race, and because the other competitor, the U.S., discovered superior manufacturing techniques leading to far greater levels of output by 1945, this techno-nationalist intervention has been judged to have been a failure.

United States

By contrast, we can draw a straight line from those companies that successfully developed the mass production of penicillin in the U.S. and the same companies' success with developing antibiotics a few years later. This was the event that transformed the U.S. industry and so enabled the U.S. to take the position of technological leadership in global pharmaceuticals away from Germany. Between 1941 and 1963 61.1% of the world's new and patented drug discoveries were made by U.S. firms (Cooper, 1966, p. 169). This represented a total transformation for the industry. In 1939, the U.S. industry consisted of over 1000 firms with a combined output of only $150 million. By 1957, sales of antibiotics alone were $406 million, with tranquilizers and cortisone/hydro-cortisone products totalling another $283 million. The protection afforded by patents meant that the industry became highly concentrated, and almost this entire output in 1957 was supplied by only 20 firms. Over half of antibiotics were manufactured by just eight firms, all of which had been among the most heavily involved with the U.S. government's wartime penicillin programme (Abbott, 1987, p. 152; Mahoney, 1959, p. 4).

While the U.S. industry in 1940 consisted of bigger and more technologically advanced companies than in the U.K. (outside of Wellcome), the leading U.S. producers were still small businesses that possessed nothing like the research capabilities of the leading German companies. As already noted, very few U.S. producers had been able to manufacture German goods after acquiring formerly German-owned U.S. patents and plants in the 1920s. American pharmaceuticals producers had instead focused on non-research-intensive sectors like toiletries in the 1930s (Abbott, 1987, p. 104; Athreye & Godley, 2009; Carlisle, 1987, p. 53; Godley et al., 2019; Kahn, 1975; Slinn, 1999). Correspondingly, research efforts commanded a low priority. Abbott, the research leader in the 1920s and early 1930s, spent only $100,000 on research in 1924 (Abbott, 1987, p. 88). Upjohn, another relative leader in research, employed just 15 people in its Research Division in 1933 (Carlisle, 1987, p. 50). Despite claiming to be research-focused, Lilly and Merck spent tiny amounts on research in the early 1930s (Godley et al., 2019). The most research-intensive producer in the U.K., Wellcome, budgeted three times more per annum than Abbott, and employed between 190 and 200 research staff, far more than any U.S. firm (Church & Tansey, 2007, pp. 91, 316, 319–20, 322).[3] By contrast, the leading German firms were much more research focused. Data are very scarce, but Schering, the smallest and the least research-intensive of Germany's principal firms, spent RM 1.4 million a year in 1929 on research, or nearly £70,000 (or $340,000, Kobrak, 2002, pp. 118–21).

Compared with industrial research in the U.S. overall, pharmaceuticals was an anomaly. Industrial research in the U.S. underwent a massive expansion (notably in electricals and in the broad chemicals sectors) during the inter-war period (Sanderson, 1972). The pharmaceuticals sector was held back by its continuing poor reputation among U.S. universities and academics' reluctance to collaborate; something which was only slowly rectified during the 1930s (Swann, 1988; Godley et al., 2019). The total research chemists employed in the industry's leading four firms increased from just 26 in 1920 to 147 in 1940, from an average of 6.5 to 36.7 per firm (Carlisle, 1987, p. 72). This was a more than five-fold increase, but it still meant that the leading U.S. firms had relatively few scientists compared to their German peers (and indeed the U.K.'s Wellcome). As argued by Parke Davis (1999, p. 360) "research in the pharmaceuticals field [in the U.S.] really came into its own in the late 1930s and early 1940s, stimulated by the demands of World War."

This underlines how the absorptive capacities in research in both the American and British industries were still weak at the onset of World War II. American Merck (which was considered by 1940 to have become the most research-intensive of all the U.S. pharmaceuticals producers after the secret transfer of research capabilities from its former German parent) employed a total research staff of only 35 in 1941 (Galambos, 1991, p. 77). Possessing sufficient research capabilities was a necessary condition for acquiring technological leadership and private sector initiatives alone had not delivered these in the U.S. What actually enabled the U.S. firms to win the penicillin race was the U.S. government's wartime techno-nationalist policy.

When the U.K. scientists went to Washington D.C. in the summer 1941 to enlist support for penicillin production, the U.S. Office of Scientific Research and Development (OSRD) immediately sought the full co-operation of the War Production Board (WPB) and approached the two leading pharmaceuticals companies in the country, Merck and

[3] There are very few data on research expenses available for any of these firms. The Wellcome figure is an estimate based on Church and Tansey stating that expenses for one of its laboratories cost £27,000 per annum between 1920–1933 (2007, p. 316). If research publications (Table 10.3: 320) are a reasonable proxy for expenditure across its laboratories, then total per annum research expenses were likely £55,000–60,000, close to $300,000, or three times Abbott's spend. We should note that U.S. producers of vaccines and anti-toxins were a little more research-intensive, but their research capabilities were not complementary to those based on synthetic chemistry (Galambos & Sewell, 1995).

Squibb, to pursue the mass production of penicillin (Bud, 2007, pp. 43–4). Pfizer, which at this point was a specialist producer of citric acid for the food and drinks industry and not a pharmaceuticals company, joined in September 1942. This brought in fermentation expertise, and while Merck, Squibb and other, later-joining, members expected that penicillin could be synthesized, it was in fact Pfizer's innovation of deep-tank fermentation in late 1943 that proved to be the breakthrough in permitting the scaling up of production (Bud, 2007; Rodengen, 1999).

The role of government policy in the U.S. in supporting, subsidizing and co-ordinating the pharmaceuticals manufacturers as they experimented and developed new manufacturing processes, seems, ostensibly, similar to that followed by the U.K. government. There were, however, key differences, but not in funding. Both governments offered direct subsidies at broadly similar levels to cover the initial expenses of R&D and the building of new factories. The U.K. government gave over £2 million from December 1943 onwards to enable six new penicillin factories to be built, in addition to its earlier support of research (Corley, 2003, p. 22). This was comparable to the estimated one-quarter of the total investment of $30 million in the U.S. penicillin programme that came from the U.S. government (or $7.5 million, which, at average exchange rates for 1941–1944, is £1.9 million, Kogan, 1963, p. 207).[4] Rather, the key difference between the two governments' approaches to the penicillin race was the level of co-ordination offered.

The U.K. Ministries of Health and Supply were content for the penicillin programme to be loosely coordinated by the TRC. The research directors of the constituent firms knew each other well; almost all had a common background as employees of Wellcome research laboratories (Church & Tansey, 2007, pp. 309, 484). However, informal coordination was not strong enough to overcome the competitive tensions and the group remained distrustful of each other and were reluctant collaborators (Liebenau, 1987, pp. 74, 77, 81). In retrospect, apart from Glaxo, which supplied 70% of all British wartime penicillin (Davenport-Hines & Slinn, 1992, p. 48), the other members of the TRC failed to respond to the nation's need. This provided a stark contrast with the U.S., where the OSRD and WPB coordinated the industry's efforts, insisting on a free exchange of information and know-how to reduce duplication of effort and to increase the speed of diffusion of information about any innovation (Quinn, 2013, p. 428). Once the WPB had obtained exemption from anti-trust laws from the Department of Justice (Quinn, 2013, p. 428), and with the special urging of President Roosevelt (Rodengen, 1999, p. 60), the collaboration grew, with over 20 firms investing in deep-tank fermentation plants. Apart from Merck, Squibb and Pfizer, the most active participants included Lederle, Abbott, Lilly, Bristol-Myers, Parke Davis, and Upjohn. These firms all went on to become the world's leading producers of the antibiotics (Abbott, 1987, p. 121, 132; Bud, 2007; Corley, 2003; Engel, 1961, p. 90; Kahn, 1975, pp. 136–7; Kogan, 1963, p. 207; Liebenau, 1987; Shook, 2007, p. 302). Thus, whereas in the previous episode, the techno-nationalist policies of the U.S. and U.K. governments between 1918 and 1939 failed due to a lack of absorptive capacity in the two countries' domestic industries, in this instance, the role of the U.S. government's co-ordination of knowledge acquisition enabled U.S. firms to apply and exploit this new knowledge for capability development.

The nature of scaling up penicillin manufacturing was one that required extensive investment in R&D by the companies (Bud, 2007, p. 45). Merck, for example, increased its number of researchers from 35 in 1941 to over 500 by 1945 (Galambos, 1991, p. 77). Screening samples, planning and testing different fermentation and purification techniques, then scaling up from laboratory to mass production required a huge effort. Wartime "penicillin researchers revolutionised manufacturing processes for the entire pharmaceuticals industry" (Quinn, 2013, p. 432). Given the German companies' initial advantages in manufacturing and research, had the war not led to such an extreme techno-nationalist intervention by the U.S. government, Bud (2007, p. 77) speculates that penicillin manufacturing may well have been developed first in Germany, and German firms would have retained their technological advantages. However, the impact of the forced dissemination of knowledge among the participating firms along with the additional investments in capacity meant that the U.S. industry acquired an advantage. By contrast, the U.K.'s efforts were less effective, despite similar levels of subsidy. For example, the TRC remained equivocal about deep-tank fermentation, and without effective industry-wide coordination, no individual firm was willing to make such a major investment in new facilities (Bud, 2007, pp. 49–50; Davenport-Hines & Slinn, 1992, pp. 146–8).

Those few U.S. firms that had developed penicillin manufacturing and research capabilities were the same firms that subsequently discovered broad-spectrum antibiotics in the 1950s and then dominated global sales (Bud, 2007; Engel, 1961, p. 106; Mahoney, 1959, pp. 45, 155). Their "joint achievement was to give the U.S. industry a central role in the future of antibiotics" (Bud, 2007, p. 44) and the windfall profits were invested back into research (Bud, 2005). Abbott's research expenditure reached $5.6 million in 1958, with a total research staff of over 700 (having been 284 in 1955) (Abbott, 1955, p. 11; Abbott, 1987, p. 155). Upjohn's

[4] Temin (1980, p. 86) states the U.S. government gave $3 million to support industry research, but we don't know if this is in addition to the $7.5 million or just one part of it. The U.S. government also permitted accelerated depreciation on construction costs (Temin, 1980, p. 66).

research staff grew to 297 in 1950, and then to 421 in 1952 (Engels, 1961, p. 104). Pfizer spent $13 million in 1959 (Pfizer, 1959, p. 19) and Merck's research budget increased from $4.7 million in 1950 to $14.9 million in 1957 (Sturchio & Galambos, 1991, p. 185). This unparalleled investment in scaling up research then led to the delivery of the second wave of discoveries: in steroids and contraceptives, in hydrocortisones and anti-hypertensives, and in sedatives and tranquilizers, which gave the American industry its global dominance during the 1960s and 1970s, and so to confirm it had acquired technological leadership from the German firms. The catalyst for this was the U.S. government's techno-nationalist pursuit of penicillin capabilities for its domestic industry during wartime.

Episode 3. Weaponizing monopsony: Incentivising research through price discrimination in the U.K.'s National Health Service

Of the three episodes of techno-nationalist attempts by governments to support their indigenous pharmaceuticals industries in acquiring research leadership, the most remarkable (and least well known) is the U.K. government's intervention from 1957 onwards. This led to a dramatic increase in research capabilities in the British pharmaceuticals industry, leading to British firms developing the most innovative, global blockbusters during the 1970s (Thomas, 1994, pp. 453–7). As Thomas (1994, p. 457) notes, "concentrating innovative effort into a handful of products discovered by a handful of firms in Britain leads to significant global success." Little of the existing business history literature on British pharmaceuticals has outlined just how significant an achievement this was. It is worth spelling out just how far behind British firms had been left by those in the U.S. during the 1950s.

In 1953, the total sum spent on research across the entire U.K. pharmaceuticals sector was £2.8 million, less than Merck spent alone (Cooper, 1966, p. 168; Sturchio & Galambos, 1991, p. 185). The majority of this came from the research budgets of Wellcome, Glaxo, and the newly formed ICI Pharmaceuticals division, each of which spent around £½ million. Smaller companies, such as Allen & Hanburys, May & Baker, Boots, British Drug Houses and others will have made up almost all the rest, to which can be added the efforts of Beechams, newly committed to pharmaceuticals research in 1953, which was spending around £200,000 (see Table 1, below). By 1953, there were a number of manufacturing subsidiaries of overseas MNCs, but apart from May & Baker (which was owned by Rhone Poulenc of France since 1927), very few had anything other than the smallest of research laboratories (Godley et al., 2025). This was soon to change.

The leading U.S. antibiotics producers changed what had been a longstanding policy of how they addressed international markets. Up until the early 1950s, they had typically approached the British market through cross-licensing agreements with their British peers, but with the prospect of enormous international sales of their patented antibiotics, they decided no longer to license production and instead to establish their own production units in the U.K. (Slinn, 2008). These new manufacturing subsidiaries were explicitly designed not only to serve the British market but to also become export hubs and serve those markets either close to the U.K. or within the British zone of interest.

This led to an acute dilemma for the British companies. They had largely foregone any significant investment in research to identify new products. Glaxo, the most innovative of the leading British firms in the immediate post-war period, had no new products in its research pipeline (Davenport-Hines & Slinn, 1992, pp. 183–4). Compared with their U.S. peers, not only was their expenditure on research relatively low, but it was falling further behind. Pfizer, Merck, Lilly, SKF, Abbott, and Parke-Davis were all significantly bigger firms, with annual sales of pharmaceuticals twice or more that of Glaxo, and they also devoted a higher proportion of sales to research (Davenport-Hines & Slinn, 1992, pp. 167–74, especially Table 5, p. 169). Glaxo's research expenditure for 1957 at £540,000, or $1.5 million, was only one-tenth that of Merck's (Davenport-Hines and Slinn, 1992, Table 5, p. 169; Sturchio & Galambos, 1991, p. 185). If the U.K. firms were no longer going to be able to license the U.S. products for sale in their own markets, they were facing an existential threat; developing new and better therapies was therefore critical. Then, from the late 1950s onwards, the subsidiaries of the U.S. MNCs began to expand their research facilities in the U.K. (Davenport-Hines & Slinn, 1992, pp. 193–5; Godley et al., 2025). In 1961, the total value of research carried out in U.K. pharmaceuticals had increased to £9 million, but the subsidiaries of overseas MNCs were now responsible for nearly two-fifths (see Table 1). The additional competition for scarce British research scientists further disadvantaged the indigenous producers.

The fundamental problem facing British firms was one of scale. They were too small to compete in research. Industrial research in Britain was typically only carried out in large firms (Sanderson, 1972). Wellcome was the only pharmaceutical business that employed large numbers of research staff (Edgerton & Horrocks, 1994). Beechams would later emerge as one of the leaders of British research effort, but in the early 1950s, it was only just beginning to focus on pharmaceuticals research (Corley, 2011). ICI conducted some research, but it only established a stand-alone pharmaceutical division in 1953 (Quirke, 2009, pp. 380–1; Reader, 1975, pp. 458–9). By the mid-1950s these three, along with Glaxo,

Table 1 Research expenditure in U.K. Pharmaceuticals, 1953–1970 in nominal £ million—total industry expenditure, that from U.K. owned firms, and from U.K. subsidiaries of overseas MNCs

	Total UK industry R&D	U.K.-owned firms	Subsidiaries of MNCs	U.K.-owned share (%)	FDI share (%)
1953	2.8	2.52	0.28	90	10
1961	9	5.5	3.5	61	39
1965	11	7.15	3.85	65	35
1970	30	24	6	80	20

Sources. *Total industry R&D*: 1953: Cooper (1966, p. 168); 1961: Foreman-Peck (1995, p. 102); 1965: Merck Sharp & Dohme (1966, p. 5); 1970: ABPI (1992, Fig. 22, p. 27). Note that Cooper (1966, p. 170) states pre-1953 R&D in U.K. pharmaceuticals was "insignificant"

U.K.-owned firms and subsidiaries: 1953 estimated from Davenport-Hines and Slinn (1992, p. 165) (for Glaxo, ICI, and Wellcome). Beechams estimated from Corley (2011, pp. 183, 187, 190, 196, 199–200). Smaller firms estimated from Davenport-Hines and Slinn (1992, p. 196); and Foreman-Peck (1995, pp. 164, 166–8). Overseas subsidiaries from Godley et al. (2025); and inferred from Cooper (1966, p. 185); 1961: Cooper (1966, pp. 180–1); Davenport-Hines & Slinn, 1992, p. 198; 1965: Cooper (1966, p. 185 Table 58, pp. 174–5); and 1970: Jones (2001 Table 21, p. 455); Wellcome Foundation (1975); Corley (2011, p. 216); ICI inferred from Reader (1975) and Quirke (2006). Smaller companies' expenditure estimated from Foreman-Peck (1995, p. 169)

were committed to research-led innovation, but the rest simply remained too small. It was these four larger, research-focused firms that were therefore the most exposed to U.S. subsidiary competition. Consequently, these four firms opened discussions with the U.K. government about possibilities to support indigenous research capabilities. This would prove to be the decisive moment in the British industry's transformation.

The National Health Service (NHS) was established in 1948, offering a universal health care system for all British citizens. This was the single most important policy initiative by the new Labour government in its attempt to redefine the country's social contract after what had been an almost pyrrhic victory in World War II. As the U.K. navigated through the difficulties of dismantling the empire and reduced geopolitical influence during the 1950s and 1960s, the NHS attained totemic status on the home front. Prescription medicines were free to patients, paid through general taxation. This meant that the U.K.'s Ministry of Health negotiated with the pharmaceutical providers over pricing (Corley, 2003; Slinn, 2005). During the mid-1950s the leading British companies (through the auspices of the Association of British Pharmaceuticals Industry) together with the Ministry of Health agreed the Voluntary Price Regulation Scheme (VPRS), which became operational in 1957 (Davenport-Hines & Slinn, 1992, p. 176). As Thomas (1994) explained, the impact of the VPRS on the future of the British pharmaceuticals industry was profound. The VPRS offered two methods to calculate the price to be paid for the medicines used by the NHS. The principal method was to pay companies the average sale price they received in overseas markets. However, for those companies which had developed new therapies, a 3-year window was permitted when they could charge higher prices to recoup the costs of research undertaken in the U.K. (Jones, 2001, p. 222).[5] This provided a strong incentive to invest in pharmaceuticals research located in the U.K. and to develop products that were successful not only in the home but also in overseas markets. It provided strong disincentives for incremental innovation with smaller research efforts (Thomas, 1994).

While the result initially favoured the subsidiaries of the fast-growing U.S. MNCs, the VPRS formula was eventually to prove decisive to the development of British research capabilities. By 1961, the U.K.-owned firms had more than doubled their collective research expenditure from around £2.5 million in 1953 to around £5.5 million, but the subsidiaries of overseas MNCs meanwhile had increased their research expenditure *14 times*, from around £0.25 million in 1953 to £3.5 million in 1961. This period also coincided with the cooling of U.S.–U.K. relations after Suez (1956), the Bay of Pigs (1961) and then the U.S. entry into the Vietnam War (1963). There was a growing realisation among U.K. policymakers of the importance of avoiding becoming too dependent on U.S. interests. This translated directly into the realization that indigenous sources of prescription medicines for the NHS should be privileged.

The mood among expert commentators about the prospects of the indigenous U.K. pharmaceuticals industry in the early 1960s was cautious. As one British commentator on the state of the industry demurred, "our progress has been levelling off" (Cooper, 1966, p. 170). However, as Table 1 shows, the early 1960s *in fact* saw a major turnaround in the relative balance of research expenditure in the U.K. The leading British firms increased their share to nearly two-thirds of what was by 1965 an industry total of £11 million, before then seeing a further dramatic increase in their share of research expenditures by 1970, when the leading British firms of Glaxo, Wellcome, ICI, and Beechams collectively counted for around 80% of a much larger total spend of £30 million.

Greater safety and efficacy requirements for new products from 1964 significantly raised the costs of R&D (Thomas, 1994) and prompted those firms whose research efforts had not led to them being able to receive a price premium from the VPRS to review the balance of benefits to conducting what was now more expensive R&D in the U.K. Several MNCs either withdrew from research in the U.K. or quietly

[5] Jones (2001, p. 222) has a fuller discussion on these and the other methods of price calculation used.

wound down efforts (Slinn, 1984; Thomas, 1994), and a period of consolidation followed. Conversely those firms where research efforts were successful continued to enjoy the NHS price premium and continued to invest back into their U.K. research centres. This tilted the balance very much in favour of those firms wanting to consolidate their research efforts into central research laboratories in the U.K. The satellite research laboratories of MNC subsidiaries were unable to replicate the levels of innovative output compared to the central laboratories of the British firms. The only overseas subsidiary to continue to expand its U.K. R&D efforts to anything like the same extent as the British firms was Pfizer (Cooper, 1966, p. 39; Corley & Godley, 2011; Mantle, 1994). Between 1970 and 1982 British expenditure on R&D in pharmaceuticals increased further by another 132% (Taggart, 1993, p. 87). Of the world's top 35 prescription drugs in 1995, ten had been discovered in the U.K., a larger number than for any other country, including the U.S. (Corley, 2003, p. 28). The challenger British government's techno-nationalist policies had proven to be successful. The U.K.'s Revealed Technological Advantage in pharmaceuticals in the 1980s was double that for Germany (Cantwell, 1995).[6]

Discussion: Lessons from the history of techno-nationalism

This short summary of three historical episodes of techno-nationalism in global pharmaceuticals has produced several important insights, which need to be elucidated. Before detailing these, we need to remind ourselves of the results of the earlier discussion about the foundational constructs of techno-nationalism. Here it was recognized that while the current manifestation of techno-nationalism is focused on digital technologies, that techno-nationalism is nevertheless fundamentally agnostic about any specific technology. Rather, the importance of technology to techno-nationalism is that it supports the ongoing development of a society's "foundational infrastructure," which enables that society to maintain or acquire superiority over its geopolitical rivals rather than lagging behind. Furthermore, while the current debate focuses on the threats to both the leading and challenger countries' national security, it was recognized that threats to a country's economic and social well-being might also act against the national interest sufficiently to trigger government interventions.

Given these foundational constructs, we are able first to recognize that even the current, hostile version of techno-nationalism is not entirely "new" (Luo, 2022, p. 551). This brief survey of one very specific kind of techno-nationalism—policies by challenger governments to acquire technological leadership—and in only one very specific technological field—global pharmaceuticals—has still been able to identify three episodes occurring between 1918 and 1970.

As the previous sections have shown, these three episodes led to different outcomes, some were successful, some were not. The first episode in the years after 1918 saw policies of asset expropriation and tariff barriers implemented by the U.S. and U.K. governments that tried to exclude the German technological leader MNCs from the U.S. and U.K. markets. Due to a lack of absorptive capacity, however, these policies failed to transfer technological leadership from Germany. The second episode saw similar attempts to exclude German MNCs' access to U.S. and U.K. markets but on this occasion U.S. and U.K. governments supplemented this policy with direct support for their domestic industries' acquisition of research capabilities. In this case the outcomes differed, with the U.K. intervention less successful than in the U.S. The U.K. government offered subsidies but minimal coordination of indigenous producers. The U.S. government followed a similar policy of direct funding but was much more vigorous in coordinating the dissemination of new knowledge and so was far more successful in creating spillover gains for the participants in the U.S. penicillin programme. This proved to be of critical importance, enabling firms' acquisition of the necessary deep-tank fermentation technologies and research capabilities. This then gave them a superior advantage over German producers in the search for broad-spectrum antibiotics in the 1950s. Active participants in the U.S. penicillin programme therefore dramatically increased the speed with which they were able to acquire technological capabilities. Even under depleted post-war conditions, the German firms would surely have been able to match American efforts in penicillin had the U.S. government not coordinated the diffusion of technological innovation among U.S. firms.

Finally, the third episode hinged on a subsidy from the U.K.'s NHS, a price premium for new drugs that were the product of British-located R&D. Initially, it was the manufacturing subsidiaries of the U.S. MNCs (which by then were the technological leaders) that disproportionately responded by expanding their research laboratories in the U.K. However, the scale required in R&D for firms to pursue innovative blockbusters increased markedly, and so the U.S. MNCs faced a dilemma. Should they try and concentrate all their research efforts into a central laboratory based at their headquarters, where the costs of coordination and control would be minimized, or should they increase investment in their smaller U.K. research laboratories to benefit from the subsidy? The result in the 1960s was for subsidiary research centres in the U.K. to become satellites of the parent company central laboratories, or "proto-competence creating subsidiaries" (Godley et al., 2025). By virtue of

[6] Cantwell's method meant that unfortunately he could not include the U.S. as a comparator.

their relatively smaller research pipelines within their U.K. research facilities, the MNCs attracted a smaller share of the NHS subsidy. The rapid increase in pharmaceuticals research expenditure after 1961, and especially after 1965, was therefore almost entirely a product of investment by British firms. This episode of techno-nationalism transformed the prospects for the U.K. industry in future years.

Reviewing these different outcomes enables several themes to emerge. First, and perhaps most obvious, is that the success of a challenger government's techno-nationalist policies does not depend on the degree of restrictions imposed on the technological leader for access to the challenger market. It is difficult to conceive of more extreme techno-nationalist interventions than those pursued by the challenger U.S. and U.K. governments against German pharmaceutical producers during and after World War I. Yet they failed. This is an important observation because of the question posed by Luo (2022, p. 564), regarding what might happen to the future of international business if current retaliatory cycle of techno-nationalist policies becomes even more severe (a question he described as being "the biggest question ever" in IB). The answer to Luo's question that emerges from this short historic survey would be that despite the severity of the policies, outcomes are contingent on other factors: first, the presence of sufficient absorptive capacities among the challenger country's domestic industries and their constituent firms' abilities to build on their existing research capabilities to operate somewhere close to the industry's technological frontier, and second on the costs to MNCs of adopting mitigation strategies. Several leading German producers, for example, avoided the costs of U.S. and U.K. techno-nationalist policies by "cloaking" the origins of their U.S. and U.K. subsidiaries, when the costs of "cloaking" were less than the costs of compliance.

The second theme to emerge relates to the nature of the threat to national interests. While the first two episodes were associated with wartime threats to U.S. and U.K. national security, the third was a threat to U.K. national social well-being. All three episodes were characterized by zero-sum thinking among policymakers in response to the perceived geopolitical tensions. This was most obviously the case between wartime combatants. It was also true, however, of postwar Britain, which had coalesced around a social contract which emphasized that victory in World War II must be followed by a prosperous peace, with the dividends shared across society. This elevated the significance of the NHS. The realization that the majority of prescription medicines was supplied by the subsidiaries of U.S. MNCs, combined with the cooling of U.S.–U.K. relations in the late 1950s and early 1960s, led to policymakers agreeing that the prospect of not having guaranteed indigenous supplies of advanced medicines was a threat to the national interest. It led to the design of the VPRS, which so explicitly favoured domestically based research. This techno-nationalist intervention by the British government did not impose costs on foreign firms' access to the British market on the grounds of national ownership; that would have been politically difficult given the source of this specific threat was U.S. firms. Rather it provided strong financial incentives in favour of those firms that located central research laboratories (or similar) in the U.K. In this instance, therefore, the techno-nationalist policy instrument was location-based rather than firm-based. The escalating costs of conducting research in pharmaceuticals at this time meant that the research-intensive British producers benefited disproportionately from concentrating all their research activities in the U.K. and so from the VPRS-related subsidy. For the U.S pharmaceutical companies, the costs of operating central research laboratories in the U.K. as well as in their home market were too high.

This latter episode illustrates that challenger country techno-nationalist policies do not need always directly to target the technologically leading MNCs. In this case, the policy focused on supporting research capabilities within the location of the U.K. rather than British firms *per se*. This was fundamentally different from the other example of a successful techno-nationalist policy, where the U.S. government targeted the development of technological innovation among U.S. firms during World War II.

On the basis of this survey of the historical evidence in the pharmaceutical industry, it is now possible to propose a typology of variants in challenger government techno-nationalist policies from the perspective of differences in both the mechanisms that were used by governments to promote indigenous innovation and the specific policy targets identified by governments. Setting aside the examples of unsuccessful policies, which focused on asset expropriation and tariff barriers, we restrict our typology to the two successful episodes. The episode of forced coordination of technological innovation by the U.S. government during World War II is an example of a technology-push intervention, whereas the episode where the British government offered a price premium to sellers of prescription medicines to the NHS was a demand-pull policy. Moreover, as already noted, this latter episode was a policy that targeted the location—research activities in the U.K.—rather than firms. In Fig. 1, we have correspondingly differentiated along the vertical axis between the two mechanisms of technology-push and demand-pull policies and on the horizontal axis between the different targets of firm-based and location-based policies.

In this typology of successful policies, two cells remain vacant, those of technology-push/location-based policies and demand-pull/firm-based policies. One of the lessons of this historical review of techno-nationalism in the pharmaceutical industry is that when guided by techno-nationalist thinking, policymakers need to be cognisant of industry conditions, craft their instruments carefully and be clear

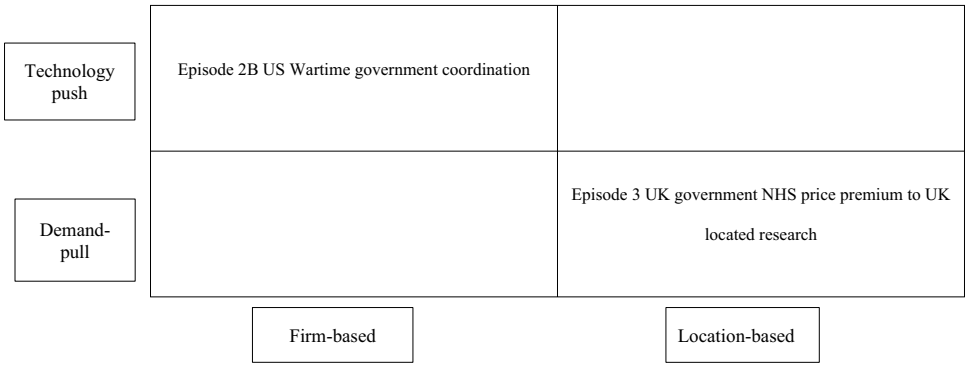

Fig. 1 Typology of variants of techno-nationalist policies

on their objectives. Thus, it might be that in the years to come, within a context of increased export controls, tariffs and subsidies, new variants of techno-nationalism emerge to fill these vacant cells. Or, alternatively, that the policies of "new" techno-nationalism discussed by Luo (2022) evolve in such a way to occupy these spaces. Either way, new opportunities for future research to explore variants of techno-national policy are opened up.

Conclusion

Recent IB literature on the implications of increasing levels of techno-nationalism has called for new theorizing and empirical exploration (Witt, 2019b). Earlier episodes of challenger governments pursuing techno-nationalism and any retaliatory responses would appear to be useful candidates to support inductive theorizing through historical analogy. This paper has explored the different episodes of changing technological leadership in global pharmaceuticals between 1918 and 1970, identifying different approaches adopted by the U.S. and U.K. governments at different times. While remaining cautious given the necessary caveats about fragmentary historical data, this survey's first contribution to the IB literature is that it shows that in the past challenger country governments have pursued a variety of techno-nationalist policies, some far more hostile to MNCs than even the most severe techno-nationalist policy operating today. 'New' techno-nationalism is therefore not in fact so new. The study's second contribution is to identify that these differing policies met with varying degrees of success, not because of their severity, but because of the varying levels of absorptive capacity of the domestic industries. The presence of sufficient absorptive capacities among domestic producers is a pre-condition for techno-nationalist policy success, but not a sufficient condition alone. Neither of these two findings will be especially surprising to IB scholars. Our third contribution, however, does make a significant contribution to the IB literature, where we have shown a variety of successful challenger government policies in the past that have focused both on technology-push and demand-pull mechanisms, and on firm-based and location-based targets. IB scholars therefore need to take into account this variety of successful tecno-nationalist policies that have been pursued in the past as they try to better understand the phenomenon today. Finally, we also contribute to the discipline of business history by exploring the relative importance of government policy in determining technological leadership in global industries, which was largely omitted from several of the canonical works with their disproportionate focus on firm strategy (for example, Chandler, 1990, although see the recent critique by Langlois, 2023).

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