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The Economic Logic of Policies to Address Import Dependence in Clean Energy Goods

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The Economic Logic of Policies to Address Import Dependence in Clean Energy Goods

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Abstract

The fragmentation of global supply chains and rising geopolitical tensions have spurred concerns about import dependence. These concerns are particularly pronounced for clean energy technologies and critical raw materials, which are not only essential for climate change mitigation but are also viewed as important drivers of future productivity gains and economic growth. This paper contributes to the debate by analyzing challenges related to import dependence from the perspective of market failures, asking under which circumstances import dependence is the symptom of a market failure. On this basis, we discuss ways to assess the benefits and costs of different policies that have been proposed to address import dependence, derive implications for policy makers, and identify future research needs.

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1. Introduction

Globalization has led to increasingly interconnected supply chains (Timmer et al. 2014). While economic integration facilitates an efficient division of labor between countries, the Covid-19 pandemic also demonstrated how disruptions in production in one country can have repercussions in other parts of the world (Javorcik 2020). It has, however, also yielded important lessons on how global trade can act as a buffer for domestic shocks (Bonadio et al. 2021). More recently, Russia's invasion of Ukraine has clearly shown the perils for Europe of relying on natural gas imports from a dominant supplier (Liadze et al. 2023). Increasing geopolitical tensions give rise to concerns about 'weaponized interdependence' (Farrell and Newman 2019), i.e. countries using the threat to cut off supplies of important commodities or technologies in a coercive manner.

Import dependence is an essential element of the policy discussion on clean energy technologies and the critical raw materials needed to produce them. Here, we use 'clean energy goods' to denote both categories. Clean energy goods are not only crucial to achieve international climate targets but are also increasingly regarded as important drivers of economic growth and employment. According to estimates by the International Energy Agency, clean energy accounted for 10% of global GDP growth in 2023 (IEA 2024a). China currently dominates international supply chains for solar panels, batteries, and electrolysers for hydrogen (see Figure 1), and is also rapidly increasing its share in the market for electric vehicles . Furthermore, clean energy technologies require certain critical raw materials for which China also is a central actor, controlling almost the entire global market for e.g. graphite and rare earths and more than half of the production of refined lithium and cobalt (IEA 2022b).

This paper analyzes problems of and solutions for import dependence in the language of market failures. Some previous literature has analyzed the importance of global supply chains and discussed policies to increase their resilience (see Johnson (2018) and Antràs and Chor (2022) for concise reviews of the respective literature). However, only one paper (Baldwin and Freeman 2022) has attempted to explicitly relate policies addressing supply chain issues to specific market failures. To our knowledge, our paper is the first to focus on clean energy goods. Although our assessment of market failures and policies is of a general nature and can be applied to any industry, we focus on issues that are specific to clean energy goods. Rapid technological learning and expected market growth fuels policy makers' hope that these technologies can contribute to the modernization of the economy, while at the same time providing global climate benefits by mitigating carbon emission. In addition, by reducing dependence on fossil fuel imports, clean energy technologies have important implications for national security (Beaufils et al. 2025).

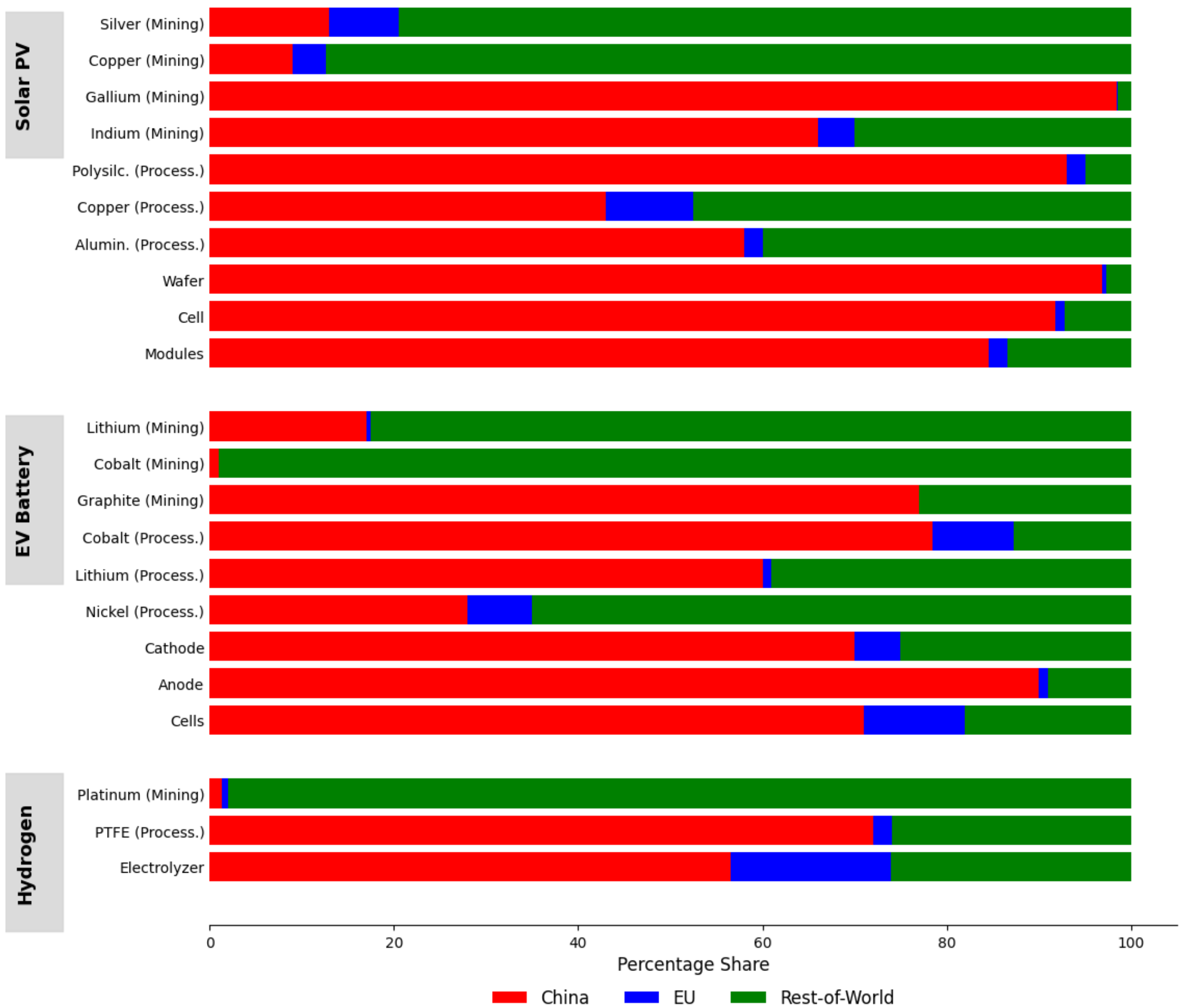

Figure 1: Estimated shares of world regions in mining, material processing and manufacturing of clean energy goods. Data refers to year 2021, 2022 or 2023, depending on latest available. Compiled by the authors from different sources, including IEA (2024b), IEA (2022a), Raw Material Information System (2024), Minerals and Metals Facts (Natural Resources Canada 2024), World Nickel Factbook (INSG 2024), McKinsey (2024), U.S. Geological Survey (2024).

This paper asks which types of policies self-interested governments can adopt to benefit their own country. To keep our discussion tractable, we focus on those market failures and policies that are most pronounced for technologically advanced countries. We draw our examples predominantly from the EU, which has recently reconfirmed the central role of decarbonization for its economic development (European Commission 2024b).

Devising appropriate policy responses to import dependence requires assessing trade-offs between different policy objectives. A clear understanding of the underlying market failures is essential for this analysis. Section 2 provides the starting point for our analysis by describing different conceptions of import dependence. Section 3 discusses which market failures could result in too little domestic production or too little diversification, respectively. Section 4 assesses how different policy instruments address market failures and highlights the potential benefits as well as costs of these instruments. Section 5 addresses geopolitical competition as an additional policy objective with implications for the assessment of policy choices. Section 6 discusses how the arguments presented in this paper can help inform real-world policy decisions. Section 7 concludes and presents an outlook on future research.

2. Conceptualizing import dependence and response strategies

We speak of 'dependence' when imports represent a high share of total domestic consumption and are sourced from few supplier countries or just one supplier country (European Commission 2021a). This means that a trade deficit - i.e. importing more than what is being exported - does not by itself constitute import dependence.

Reducing import dependence is increasingly recognized as an important policy objective. Whereas some emphasize the importance of boosting domestic production in sectors of strategic importance (‘reshoring’) others argue in favor of fostering trade relations with countries with strong economic ties and good diplomatic relations (‘friendshoring’) (Cerdeiro et al. 2024). In a similar vein, authors debate the extent to which ‘decoupling’ from certain trade partners is possible and desirable or whether ‘derisking’ by diversification of import portfolios constitutes a more feasible policy option (Farrell and Newman 2019). Conceptually, these terms entered the political discourse following recent policy statements by influential decision makers, including remarks on U.S.-Chinese economic relations that introduced a “strategy called ‘friendshoring’” (U.S. Treasury 2023). In the European Union, the notion of ‘strategic autonomy’, embraced as early as 2016 in the context of broader security debates (European Council 2016), has also become a defining paradigm of international economic policy that prioritizes ‘de-risking’ of supply chains (European Commission 2023c).

Import dependence has been discussed for several issue areas, ranging from imports of energy carriers (currently oil and gas, and potentially green hydrogen in the future), pharmaceutical substances (antibiotics, vaccines) and medical equipment (face masks, ventilators), to high-tech products (micro-chips) as well as clean energy products (solar PV panels, batteries, electric vehicles, and the associated critical raw materials). For each of these commodities specific reasons underlie the concern about excessive imports. These include, e.g., short-term energy security in the case of gas and oil imports, or crisis-preparedness for medical substances and devices. The latter two are short-term concerns and focus on security of supply, i.e. it does not matter so much by whom and from where these goods are supplied, as long as the supply is reliable. A different rationale applies to high-tech and clean energy goods, such as electric vehicles or batteries, where short-term supply is less important than securing actual domestic production capacities, underpinned by mid- to long-term industrial policy considerations of competitiveness and development of domestic value chains. These characteristics of import dependence are illustrated in Figure 2.

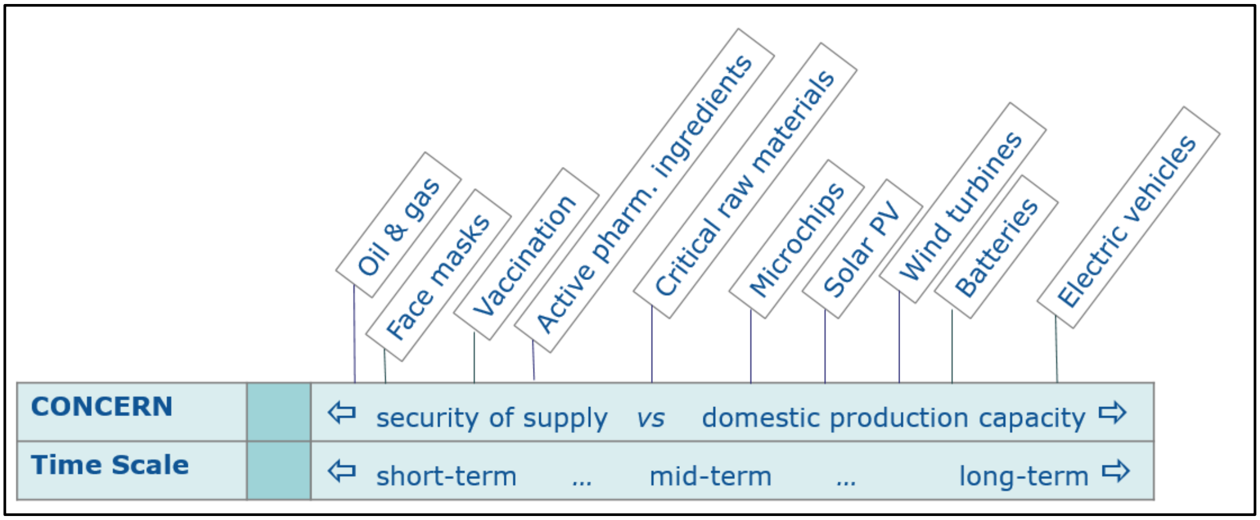

Figure 2: Different aspects related to import dependence. Note that the relative position of the specific issues shown at the top is indicative and mainly serves for the purpose of illustration.

Similarly, a relevant differentiation is whether import dependence exists for a 'flow' or a 'stock'. An interruption of 'flow' goods like fossil fuel imports would directly affect energy supply. By contrast, an existing 'stock', such as clean energy technologies, could still be used (e.g. to generate electricity) even if imports are cut off; supply interruptions would in this case merely affect capacity expansion. Moreover, it is important to account for the specific nature of the import. For instance, imports of critical raw materials differ from imports of clean energy technologies, as the former might be constrained due to their geographical concentration, whereas for the latter new production capacities could in principle be established anywhere, so that the expectation of an interruption of supply would prompt the market entry of firms from other countries, which in turn reduces the incentive to cut off supply.

A further important distinction can be made between ownership and location. For instance, even if critical raw materials are sourced from a variety of countries, the respective production might be controlled by very few firms, so that supplies could be cut off in case of geopolitical conflict. Hence, it is also important to assess to what extent domestic production that is owned by foreign firms could be subject to interruptions or could be taken over (at least temporarily). Finally, the correlation of risks between different suppliers and substitutes matters as well. Even if imports are diversified between a number of trade-partners, they could all simultaneously be affected by a geopolitical conflict or another global crisis when trade partners share joint transport routes or common geopolitical interests.

3. Market failures

From a welfare economics perspective, a competitive market equilibrium without market failures and without government intervention in domestic or international markets leads to efficient trade flows and import volumes. Governments may have other incentives to intervene in international trade flows and supply chains (Juhász and Lane 2024), but if they deploy policies purely on the grounds of removing market inefficiencies, they would have no reason to intervene against high levels of import dependence This section focuses on understanding the relevant market failures. As distributional aspects can be addressed by targeted transfers or the broader income tax scheme (Kaplow 2024), we focus on allocative efficiency. Yet, we account for the possibility of market failures due to which distributional objectives cannot be achieved in an optimal fashion so that 'second-best' policy responses will be needed to e.g. prevent job losses or inequitable distributional outcomes.

The debate about import dependence frequently conflates the goal of reducing overall imports to boost domestic production with the objective to reduce dependence on a small number of suppliers (see Section 2). In this section, we disentangle these two motivations by analyzing which market failures might result in too little domestic production or in too little diversification and resilience, respectively. We conduct our analysis from the perspective of a self-interested government that aims to maximize national welfare.

3.1 Market failures responsible for too little domestic production

Decision makers may find it desirable to pursue policies that attract certain industries or that prevent their outmigration if these industries provide economic or strategic benefits that are not captured by market valuations (Tagliapietra and Veugelers 2020). Such benefits include localized technology spill-overs or economies of scale and agglomeration effects. Domestic production might also benefit national security in the absence of markets that can provide insurance against supply interruptions in the case of a geopolitical conflict. Moreover, as transaction costs can hinder compensating social interest groups that would lose from a clean energy transition, distributional considerations can also provide a rationale for policies that promote domestic production. Even though the latter issue is not a market failure in the strict sense, it creates a rationale for policy intervention.

Localized technology spill-overs

Technological improvements achieved by one firm will likely also yield benefits for other firms. Even though innovators can enjoy patent protection or keep certain crucial elements secret, they are unlikely to capture the full social benefits of their innovation (Levin et al. 1987). Instead, some knowledge will accrue to other firms, for instance tacit knowledge that is transferred when workers switch their jobs. With technology spill-overs, the social benefits of an innovation exceed the benefits of the innovating firms (Jaffe 1986; Spence 1984). The latter thus have insufficient incentives to invest in innovation and the market outcome will not deliver the socially optimal result. If the spill-overs are localized, which appears to be the case for most industries (Feldman and Kogler 2010), they provide an incentive for governments to implement measures to attract firms.

In principle, such technology spillovers occur for any technology and are not specific to clean energy technologies. Yet, it seems plausible that novel technologies, which possess a higher potential for innovation, exert larger spill-overs (Mehling 2025). Indeed, technologies that are central for the clean energy transition, such as renewable energy and batteries, have experienced massive cost declines in the last years. The fact that clean energy technology patents are cited more than patents for conventional energy technologies suggests stronger knowledge spill-overs for the former than for the latter (Dechezlepretre, Martin, and Mohnen 2015).

In the past, high rates of technological learning and localized spill-overs (within the same industry as well as others) for semiconductors were perceived as a market failure justifying policy intervention, such as public support schemes (Irwin and Klenow 1994). Yet, it should be taken into account that technology spillovers can also occur via imports (Keller 2010). As a consequence, reducing import dependence will only have a positive net effect on technological learning in cases in which intra-national technology spillovers are stronger than cross-border ones.

Economies of scale and agglomeration effects

For industries with economies of scale (i.e. lower unit costs at higher production volumes), production tends to be concentrated in few locations (Ethier 1982). This can result in path dependence and lock-in effects, so that production is concentrated in places that are not the most efficient locations (Redding 1999). In a perfectly functioning market environment, firms in the most favorable locations can anticipate that they will be able to dominate their competitors from abroad once they have achieved sufficient scale. However, certain market failures, such as financial market frictions, might impede them from carrying out the required investments, and the market then does not deliver a socially desirable outcome.

In a similar vein, agglomeration effects can create path dependence (Martin and Sunley 2006). Firms have incentives to locate in proximity to either consumers or other firms to keep transport costs and trade barriers low and to have access to skilled labor (Ottaviano and Thisse 2004). These effects contribute to the emergence of industrial clusters (e.g. for the production of batteries and electric vehicles). There might be multiple equilibria, and government intervention may be needed to coordinate upstream and downstream industries. For instance, establishing manufacturing capacities for batteries is often seen as a prerequisite for building up an industrial ecosystem for electric vehicles (Bridge and Faigen 2022).

When new and quickly growing industries with these characteristics emerge, policy makers could have a motivation to restrict imports as part of a wider industrial policy effort to establish key industries in their country.

Missing insurance markets and price limits

To be prepared for situations with low likelihood but high impact, such as a military conflict, the private sector could maintain reserve capacities for the production of essential goods (Simchi-Levi, Schmidt, and Wei 2014). Consumers or the government could pay the private sector for maintaining such spare production capacities. Governments could, for example, use competitive bidding schemes to incentivize the private sector to build up spare capacities for vaccines that can quickly ramp up production in case of a pandemic (Castillo et al. 2021). However, in reality such insurance markets rarely exist and to our knowledge have not been considered for clean energy goods.

It is in principle conceivable that firms build up and maintain such reserve production capacity by themselves in the expectation that they can reap high rewards for their products in a crisis situation. This incentive might, however, be undermined by the expectation that the government will intervene in the market to prevent price hikes because of distributional considerations. Such interventions have occurred frequently in food markets, where they have also distorted incentives for holding private grain stocks (Gouel 2014) It is conceivable that similar interventions would take place for clean energy goods, such as critical raw materials and green hydrogen, that are essential for key industries. For this reason, firms are likely to anticipate that very high prices - needed to justify investments in excess capacities that would only be needed with a low probability - will not materialize. This implicit limit on prices disincentivizes private investment in spare production capacities to be activated in a crisis.

Transaction costs

Finally, policy makers may have a preference to attract certain industries or maintain them because they want to achieve distributional aims or respond to political pressure from special interest groups. The reciprocal tariffs recently announced by the U.S. are a salient example of trade barriers that also follow a political rather than a purely economic logic. Economic efficiency would suggest accepting the demise of industries that are not competitive vis-a-vis foreign competition and to compensate those who lose out from the transition - for example by retraining workers, targeted public investments in affected regions, or targeted income support . Yet, such compensation might be constrained by transaction costs, which may result in insufficient information, as well as institutional constraints that prevent effective targeting of payments to potential recipients (Hanna and Olken 2018).

These concerns are perhaps most relevant for established industries that provide value-added and employment in certain regions. Even though this challenge arises for all types of structural economic change, it is especially pronounced for the clean energy transition, which requires a fundamental restructuring of e.g. steelmaking and the car industry. Policy makers may hence strategically adopt targeted measures - including import restrictions - to protect certain geographies, industries, or social groups against foreign competition and give them time to adopt clean production methods(Criscuolo, Dechezleprêtre, and Lalanne 2023).

3.2 Market failures responsible for too little diversification and resilience

Firms have a motivation to avoid interruptions in production. Ample empirical evidence documents that firms indeed undertake substantial investments to diversify their supply chains and keep stocks of critical inputs (Baldwin and Freeman 2022). Nevertheless, some market failures result in underinvestment in activities that would increase their resilience to supply shocks. These include coordination failures and imperfect contingency markets, information costs, moral hazard and the expectation that policy makers will intervene in times of serious crises as well as myopic behaviour.

Coordination failures and imperfect contingency markets

When there are upstream and downstream linkages between firms in a production network, i.e. because one firm's output constitutes an essential input for other firms, these firms have an incentive to coordinate (Malhotra, Schmidt, and Huenteler 2019). To some extent, such coordination is indeed happening, for instance through long-term supply contracts.

However, concluding such contracts can involve high costs and complex negotiations (Dugoua and Dumas 2024). In today's highly fragmented value chains, information asymmetries (e.g. firms don't know the suppliers of their suppliers) are likely, which might lead to an underestimation of supply chain vulnerabilities. Moreover, there are several reasons for interrupted supply against which such contracts cannot offer protection, for instance cases of *force majeure* such as natural disasters. Likewise, in the case of geopolitical conflict, such contracts might not be enforceable, as the country in which the supplier is located would be unlikely to pursue legal action and might instead even take active steps to interrupt trade relations, e.g. by means of an embargo. Imperfect contingency markets could thus be an important motivation for ensuring a high domestic supply of goods that are crucial for national defence.

Information costs

Effective diversification requires information not only about one's own entire supply chain, but also about opportunities to switch to different suppliers. For many firms, especially small and medium-sized ones, the relevant information might not be readily available or costly to gather (WEF 2021).

Information constitutes a club good that does not get diminished if it is shared among a higher number of actors. For this reason, provision of information yields economies of scale, and it would be worthwhile for firms to cooperate to establish a joint system to gather and process supply chain information (Arrow 1996). However, this might be hampered by the complexities of negotiating and agreeing on a common reporting standard, and some firms might hesitate to share their private information with competitors. For this reason, firms are unlikely to have the socially optimal amount of information for efficient supply chain risk-management.

Moral hazard and policy makers' lack of commitment

Firms can adopt measures to alleviate the risks of supply chain interruptions. This includes diversifying their supply chains and keeping sufficient reserves. Incentives for this might, however, be diluted by the expectation that, in the event of a serious crisis, policy makers will intervene and assist firms (Nemet et al. 2017), for instance by supporting collaboration with new suppliers or providing financial assistance to deal with higher world market prices. This consideration is of particular importance for firms that are deemed to be indispensable, either because they produce essential goods, such as healthcare products, or because they represent a large source of employment and regional value-added (Strahan 2013).

In all these cases, anticipating public support in times of crisis creates a moral hazard problem that results in insufficient precautions taken to prepare for risks that have a low probability but a high impact. In a similar vein, as managers do not bear the full costs facing the firm in case of a crisis, they might have insufficient incentives to mitigate risks.

Myopia

If firms act in a myopic way – i.e. applying effective discount rates that are higher than the marginal return on capital – they will do too little to address challenges that may arise in the far future, such as interruptions of critical supply chains.

The academic literature is not conclusive about the relevance of myopia. Some authors have emphasized the principal-agent problem of managers' boosting short-term performance to increase their wage and reputation (Narayanan 1985), and to reduce the risk of a hostile takeover when shareholders are imperfectly informed about the firm's situation (Stein 1988). On the other hand, it has also been argued that, due to well-informed investors with long time horizons, financial markets may punish short-sighted investment behavior (Tong and Zhang 2024). This latter effect seems to dominate, as recent studies find little empirical evidence of myopia for firms (Maksimovic, Phillips, and Yang 2023). Nevertheless, myopia cannot be completely ruled out and should be considered as a potential reason due to which import dependence emerges as a symptom of an underlying market failure.

4. Policy Instruments

Assuming that import dependence is the manifestation of one or more market failure, as discussed in the previous section, this section considers measures that policy makers can implement to promote domestic production and diversify supply chains for goods that are deemed to be of strategic importance. We discuss which market failures are addressed by a given policy option. In many cases, policies address the relevant market failures only indirectly, and a multitude of inefficiencies that are not fully rectified by public policies prevail. Hence, the measures discussed here should generally be regarded as second-best policies (see Section 6.1).

4.1 Policies to promote domestic production

Policy makers frequently adopt policies to attract investment and grow industries that are considered of economic or strategic importance, or to prevent their relocation abroad. For instance, the EU's Net-Zero Industry Act aims for at least 40% of 'strategic net-zero technologies' to be manufactured in the EU by 2030 (European Commission 2023b). In the academic literature, there is a long-standing debate about the effectiveness of such industrial policies. Most researchers recognize the role of informational limitations when governments try to 'pick winners' and the challenges to limit the influence of vested interests on policy design (Krugman 1993). Nevertheless, some argue that well-designed industrial policies can help to surmount important market barriers and point to the successful use of industrial policies to spur economic development in e.g. Southeast Asia (Aiginger and Rodrik 2020). Against this background, the following sub-sections discuss the potential role of technology support, trade restrictions and public investment to promote domestic production.

Support for research, development and deployment

A wide range of policies can support research and development as well as the establishment of production facilities for industries of economic or strategic importance, such as semiconductors. Ideally, these measures should be targeted as closely to the market failure as possible (Goulder and Parry 2008). For example, if knowledge spill-overs occur mostly in the invention phase of a new technology, direct subsidies for research and development are most appropriate, whereas production subsidies can help progress along the learning curve and reduce unit costs for technologies that are closer to market-readiness (Edler and Fagerberg 2017). Technologies to remove greenhouse gases from the atmosphere are an example of the former, and solar panels - at this point in their technology maturity - are an illustration of the latter. Firms from strategically relevant industries are in many cases granted tax breaks to make investments more attractive. Some countries also create special economic zones to foster agglomeration and create synergies between different but related industries (Lu, Wang, and Zhu 2019). In a similar vein, place-based industrial policies are increasingly used to buffer the economic decline of regions that are most affected by structural change (Busso, Gregory, and Kline 2013), so that declining economic activity in, say, coal mining could be to some extent compensated by locating plants to produce batteries in the respective regions.

Another potential form of support includes the provision of public infrastructure, e.g. for transportation and telecommunications, to improve companies' business prospects. For instance, empirical evidence suggests that public measures to increase the number of charging points has played an important role for the rapid uptake of electric vehicles (Springel 2021). In principle, measures to support the use of clean technologies, such as feed-in-tariffs for renewable power or financial support for electric vehicles, are independent of where the respective technologies have been produced (Fischer and Newell 2008). However, policy makers frequently include local content requirements that make the support conditional on sourcing components or materials from domestic production. Even though such support schemes have repeatedly been challenged before the WTO, the U.S. Inflation Reduction Act of 2022 (IRA) includes provisions that confer additional financial support to technologies produced in the U.S. or in countries with which the U.S. has a preferential trade agreement (Noll, Steffen, and Schmidt 2024).

Trade restrictions

Trade restrictions are an obvious way to shift demand from imported to domestically produced goods. Import tariffs can shift the terms-of-trade and patterns of comparative advantage, and non-technical trade barriers, such as product standard and labeling requirements, may further protect domestic producers against foreign competition (Trebilcock and Fishbein 2007). Voluntary export restraints applied by trade partners, such as export quotas implemented by Japan to limit car exports to the U.S. market, can also limit imports and might be politically less contentious, as associated revenues or scarcity rents accrue to trade partners, unlike the revenues of import tariffs (Pomfret 1989).

Trade restrictions raise the price of imported goods, however. As increased competition and access to imported intermediate goods can increase firms' productivity (Halpern, Koren, and Szeidl 2015), applying trade barriers creates costs. For instance, raising the costs of renewable energy technologies will inevitably delay the transition to a low-carbon energy system (Goldthau and Hughes 2020; J. Helveston and Nahm 2019; J. P. Helveston, He, and Davidson 2022). Even though in theory trade barriers can help nascent industries become competitive, history provides ample examples of ill-targeted trade barriers that have created substantial costs without conferring tangible benefits. In addition, trade restrictions entail the danger of creating political backlash from trade partners, who frequently retaliate with trade barriers of their own.

State ownership

Another way to increase domestic production of certain goods and services is public investment in these activities. In some countries, a substantial share of the economy is state-owned. State-owned enterprises often dominate in e.g. extractive industries, basic infrastructures such as water, gas, power and telecommunications, as well as financial services (Bałtowski and Kwiatkowski 2022). Some countries also feature state-owned enterprises in manufacturing sectors, such as carmakers and shipbuilding. Furthermore, the Chinese government has recently announced plans to use state-owned enterprises to make China a leading power in key technologies (Reuters 2023).

However, governments might face considerable challenges to successfully engage in complex industries, such as clean energy technologies, in a rapidly changing market environment in which dynamic start-ups play an important role. In such settings, public-private partnerships could be a viable alternative in which the public sector maintains a minority share in strategically important companies and can ensure that a minimum supply is guaranteed for the domestic market while leaving business decisions in the hands of the private sector (WEF 2022).

4.2 Policies to foster diversification and resilience

Policies to attract domestic production are often viewed as an effective way to ensure security of supply. Yet, domestic production can also be disrupted due to e.g. large-scale environmental impacts or a pandemic. It might hence be desirable to have a diversified base of suppliers so that shortfalls from any particular source – domestic or foreign – can be compensated through other sources (Caselli et al. 2020). Options to reduce dependence from an overly narrow range of suppliers include stockpiling, the development of substitutes and promotion of circularity, tradable import rate quotas, provision of supply chain information, and measures to preempt coercion from other countries.

Strategic reserves / stockpiling

For some commodities that are essential for the economy or consumers, governments hold strategic reserves (Nichols and Zeckhauser 1977). Even though firms hold stocks to anticipate potential supply shortages (McKinsey Global Institute 2020), individual firms may underinvest in stockpiling if this activity exhibits economies of scale. In such cases, a centrally managed strategic reserve - and thus a higher level of stocks - could be economically more efficient. In addition, transaction costs and the expectation that policy makers will intervene to bail out firms in case of a supply crisis may mandate stockpiling by the government. A simple way to implement a centrally managed stockpiling system consists of a price band that releases reserves from the strategic reserve if the price exceeds a certain predefined limit (Gouel 2013).

Strategic reserves may be an appropriate approach for non-perishable items that can be easily stored. For clean energy technologies it would be less effective because the short innovation cycles mean that stored items would quickly become outdated (e.g. consider solar panels or batteries). Also, these types of products have a stock character, for which disruption caused by a supply shock would not be as severe as for a 'flow' good like green hydrogen. Strategic reserves could be a suitable option for critical raw materials, but finding an optimal design of such reserves – i.e. the rules when to buy at which price or how much to stock – remains challenging.

Developing substitutes and establishing a circular economy

Reducing demand for imported commodities is a straightforward way to reduce import dependence. One way to do so is by supporting the development of substitutes. For instance, novel sodium batteries would greatly reduce the need for lithium, which is concentrated in relatively few locations and hence creates import dependence. Reasons for why firms may underinvest in the development of substitutes are manifold, including coordination failures, lack of information, and lack of policy credibility. Governments can address these market failures by, for example, supporting research and development of substitutes, and providing information on substitution possibilities (European Commission 2022).

A further approach to reduce import demand consists in fostering a circular economy. Prominent examples include recycling of steel from scrap or lithium from batteries. Globally, about 30% of all steel and about 80% of lithium used in batteries are already recycled (Harvey 2021; Neumann et al. 2022). The Critical Raw Materials Act of the EU envisages that recycling should supply 15% of its demand for strategic raw materials (European Commission 2023a). To establish a circular economy, government intervention can help overcome market failures in secondary material markets, e.g. coordination problems in establishing a common industry standard (Kautto and Lazarevic 2020) as well as informational constraints.

Tradable or tiered import rate quotas

Policy makers might also adopt measures that directly restrict the share of imports from a single trade partner. E.g., the Critical Raw Materials Act mandates that no more than 65% of the EU's annual consumption should be imported from a single third country (European Commission 2023a).

These targets are still aspirational without concrete measures to put them into practice. Tradable import rate quotas requiring firms to hold a permit for imports in strategic sectors would be one way to ensure that these targets are achieved (Rom 1973). Providing an amount of permits that does not exceed the maximum share of imports, for instance by means of auctioning, would ensure that the targets are achieved. Tradable import permits provide an incentive to switch to suppliers from countries for which there is less demand, and only those firms who derive the highest benefits would import from locations with high demand.

Similarly, policy makers could resort to a system of tiered import rate quotas that allow a certain share of imports of a given clean energy good from any one trade partner at the default tariff rate. Such tariff rate quotas have been deployed, for instance, for EVs and hybrid vehicles in some Latin American countries. When imports from a trade partner exceed the defined quota, reflecting a growing supply chain dependency, a higher tariff level would apply to all additional imports from that country. Rather than blanket tariffs applied across the board and thus increasing the cost of all imported clean energy goods, such an approach would retain access to a defined amount of low-cost imports from foreign producers, who would also have an incentive to further reduce their costs so as to retain market share. Escalating tariff rates would eventually limit the market share of products originating from a single country to a level considered acceptable from the perspective of supply chain risk.

The main challenge for policy makers would then consist in choosing the appropriate targets or quota for import shares. Moreover, tariff rate quotas can achieve diversification on an economy-wide level, but do not necessarily ensure that individual firms are diversified. If diversification is required at the firm level, mandating maximum import shares constitutes the preferable policy.

Provision of information

With today's complex supply networks, information is crucial to allow firms to successfully diversify. Public provision of such information might be more efficient than expecting individual firms to gather information for their supply chains. Moreover, firms might not be able to compile required information on the supply chains of other firms that use similar inputs (O'Rourke 2014). Policy makers can facilitate the provision of information by defining a standardized approach for measurement and reporting. The government can also mandate firms to disclose private information and ensure confidentiality when making it accessible to other firms. Another approach that has been proposed is to develop stress-tests for supply chains to identify potential vulnerabilities (European Commission 2024a).

As the importance of global supply chains is increasingly recognized, several countries have introduced laws to account for the environmental and social impacts in third countries. For example, an EU legal act on supply chain sustainability requires due diligence for firms with more than 1,000 employees and an annual turnover exceeding € 450 million to ensure that human rights and environmental obligations are respected along their chain of activity (European Parliament and Council of the European Union 2024). This reporting infrastructure could also be used to compile relevant information to assess the networks of suppliers from which firms source their inputs.

Preempting coercion from other countries

An important concern is that supply might be deliberately cut off to exert political pressure. A credible threat of retaliation can help to preempt such coercive actions (Morgan, Syropoulos, and Yotov 2023). Building up credibility implies having appropriate instruments in place, such as trade sanctions, that could be applied if an important supplier restricts its exports. Applying such sanctions could mobilize negatively affected interest groups in the latter to lobby for the removal of the export restrictions. With a credible expectation that such trade sanctions would be applied, trade partners might refrain from imposing export restrictions in the first place. To deter export restrictions, for instance, the EU has recently adopted the Anti-Coercion Instrument, a trade defense tool designed to protect the EU and its Member States from economic coercion by non-EU countries (European Parliament and Council of the European Union 2023). Countries can also increase their resilience against coercion from other countries by forming a 'Buyers' Club' to pool demand and increase their bargaining power. For instance, the Critical Raw Materials Act includes a mechanism for joint purchasing of strategic raw materials that aims to prevent shortages by aggregating demand from EU companies and matching it with supply. Similar schemes have already been successfully used for vaccines, gas supplies and military goods.

Furthermore, strategic partnerships that create mutual dependence can reduce the likelihood of one trade partner restricting the supply of critical inputs to the other, as this would endanger other economic ties in which the partner country has an interest. For instance, in Japan the Oil, Gas and Metals National Corporation supports projects for mineral resource development and investment from Japanese companies in downstream activities for these resources, such as building smelting works, to develop strategic partnerships by the Japanese private sector (METI 2020). It is also conceivable that countries jointly hold and manage strategic reserves of critical inputs.

5. The importance of geopolitical competition

Geopolitical competition poses a further rationale to be wary about import dependence and restrict imports from certain countries. In this context, a country can be negatively impacted if its geopolitical rivals achieve progress in one or more areas. Such progress can be of a rather general nature, including economic growth or increased technological capabilities, or more narrowly focused on specific issues, such as key military capabilities (Csurgai 2018). A salient example of the former is the rise of China in the last decades to challenge the position of the U.S. as the world's dominant economic power (CSIS 2024), while efforts to prevent nuclear proliferation can be regarded as an expression of the latter (Schulte 2010). Geopolitical considerations can lead countries to focus on maximizing relative rather than absolute gains, i.e. the difference between their payoff and their rivals' payoff (Powell 1991). A further motivation for import restrictions may be retaliation against trade barriers imposed by another country. Such geopolitical considerations may also affect the choice of instruments to address import dependence.

In principle, the policies discussed in Section 4 can be used to shift economic activity away from geopolitical rivals by either incentivizing increased domestic production or production in third countries. To strategically deprive geopolitical rivals of certain economic opportunities, policy makers might aim to block their competitors' access to technologies that open up a broad range of development prospects (such as microelectronics) or that are of critical military importance (such as nuclear technology).

A further strategy to which countries can resort to isolate their rivals and limit their geoeconomic influence is to conclude agreements with third countries. For example, the EU has brought forth the Global Gateway to support infrastructure investments in low- and middle-income countries (European Commission 2021b). This provides an opportunity to strengthen economic ties and secure access to clean energy goods produced in those countries, thus reducing the risk of supply disruptions. An important goal of this approach is to offer an attractive alternative to China's Belt-and-Road Initiative based on the EU's values and commitment to a rules-based international order (Tagliapietra 2024).

6. Implications for policy design

Table 1 summarizes the market failures and policies discussed in previous sections. On that basis, this section explores the implications of these findings for policy makers. We first address some general implications for policy formulation and then discuss how modeling can help to provide a quantitative underpinning for policy design.

	Source of market failure	Policies to address market failures
Too little domestic production	Localized technology spill-overs Economies of scale and agglomeration externalities Missing insurance markets Transaction costs	Support for research, development and deployment Trade restrictions State ownership
Too little diversification and resilience	Moral hazard and policy makers' lack of commitment Coordination failures Information costs Myopia	Stockpiling Developing substitutes and establishing a circular economy Tradable or tiered import rate quota Facilitating information provision Preempting coercion

Table 1: Summary of market failures that may result in too little domestic production and too little diversification, respectively, and policies to address them.

6.1 General implications for policy formulation

Policies to address import dependence will in most cases be of a second-best nature and part of a broader policy mix. Furthermore, it is central to consider the benefits of a policy in relation to its associated costs.

Second-best policy design

In many instances, the relevant market failures, such as missing insurance markets, coordination failures or lack of policy credibility, cannot be addressed directly. Decision makers will then need to resort to second-best policies that target the outcome rather than the market failure itself (Lipsey and Lancaster 1956). Even in cases in which market failures can be tackled directly, the choice of policy instrument is often not straightforward. For instance, to promote the deployment of clean energy goods, policy makers face the choice between alternative policy instruments, such as production subsidies, tradable quota schemes or carbon pricing, and also need to decide on the stringency of the policy implemented.

It is hence crucial to not only focus on the effectiveness of a policy to spur domestic production or diversification. Instead, one also needs to consider trade-offs with other policy objectives. In particular, economic costs are crucial, as economically inefficient approaches can hamper the transition to a clean energy system. Likewise, there might be direct trade-offs between the goals of achieving more domestic production and more diversified supply chains; policy makers will need to find a way to strike a balance between these two objectives.

For clean energy goods, one also needs to take into account interactions with the climate change externality (Rodrik 2014). For instance, even if the production of clean energy technologies has localized knowledge spill-overs that would - from a narrow focus on benefits at the national level - make it worthwhile to attract more domestic production, producing them at lower costs elsewhere could accelerate the deployment of these technologies in third countries. This would in turn reduce global emissions and also benefit the country initially considering whether to implement policies to attract more domestic production (Gallagher et al. 2025).

Choosing the right policy mix

A holistic perspective on a diversified and resilient import structure requires taking into account the interrelation between different import categories, in particular with regard to the question of the cross-correlation of disruption risks and whether they are substitutes or complements. This raises the challenge of combining different policy instruments in a way that also accounts for how they impact on different market failures (Rogge and Reichardt 2016).

For real-world policy design, it will be decisive to focus on a narrow set of import dependencies and on policies that address the most important market failures (Pisani-Ferry et al. 2024). It also seems advisable to use a precautionary approach that takes into account potential impacts of policy failures. Some policies, such as providing information or stockpiling strategic reserves, will likely have a substantially lower potential for adverse side effects than others, such as trade restrictions.

Assessing the costs and benefits of policies

Policies to support the creation and growth of domestic clean industries could be welfare-enhancing. This requires, however, a careful analysis of the underlying market failures and an assessment of welfare effects. Our arguments do not suggest that all interventions to improve supply chain resilience are justified by the market failures we have identified. Such interventions also have tradeoffs, increasing the short-term cost and potentially even compromising the availability of essential clean energy goods. For example, if other countries have an inherent comparative advantage in producing solar panels, supporting this industry in the EU in order to benefit from learning-by-doing risks incurring costs that exceed the benefits of this policy.

Trade restrictions create artificial barriers that can prevent production to be located where it is most cost-effective (Deardorff 1980). Geopolitical rivalries and regulatory capture by domestic firms could also pave the way for policies that use the excuse of correcting market failures to actually advance strategic or protectionist goals. Without careful instrument choice and design, ad-hoc policies to support domestic technological development can thus reduce welfare and increase the costs of the energy transition.

6.2 Quantitative modelling to guide policy formulation

In addition to a theoretical understanding of relevant market failures and policies to address them, policy decisions can be improved by quantitative estimates of the benefits and costs of different options. For real-world policy making, it is crucial to move beyond optimal trade and industrial policies and analyze the impacts of existing or proposed measures. Several approaches that could be employed for this purpose.

Aggregate decoupling scenarios

Quantitative models can inform policy makers about the aggregate effects of decoupling. Such approaches have been employed to investigate whether renationalization of global supply chain makes countries more resilient to large shocks like the Covid-19 pandemic (Bonadio et al. 2021).

These models can also be used to study the direct welfare costs of decoupling global value chains and the change in exposure to foreign shocks after decoupling (Eppinger et al. 2023). For instance, one study considers the costs of a full trade decoupling between a "Western block" and a "China and allies" block, finding that the short-run costs of an abrupt detachment are particularly large (Baqaee et al. 2024). While informative on the costs and effects of decoupling, none of these examples specifically consider clean energy industries, and neither derive their policy scenarios from the explicit targeting of specifically characterized market failures.

Sectoral analyses in clean energy industries

Studies aiming for a complete coverage of the global economy in terms of both countries and sectors are complemented by work that focuses on specific clean energy related industries, e.g. how trade and industrial policy affect production location choices and overall consumer uptake in the electric vehicles market (Head et al. 2024). Some models also assess knowledge spillovers and directed technological change, for instance for the case of global iron and steel production via hydrogen direct reduction (Aghion et al. 2025), the road-freight sector (Noll et al. 2024) and photovoltaics (Helveston et al. 2022).

One study combines a detailed consideration of rare earth elements with a multi-industry general equilibrium model (Alfaro et al. 2025). This allows the assessment of the effect of Chinese export restrictions, showing that these measures have led to increased innovation in downstream industries relying intensively on rare earths.

Scope for future quantitative work

Compared to the range of market failures discussed in Section 3 and of policy instruments in Sections 4.1 and 4.2, the quantitative analyses display a narrow focus on policies that are either not explicitly motivated by correcting specific distortions, or target terms-of-trade-effects, external scale economies, environmental externalities, and innovation incentives. Where policies are targeted at specific market failures, they mostly focus on optimal levels of domestic production, while quantifications of optimal diversification strategies are so far lacking. Further, the policy tools considered in this literature are limited to import tariffs/export subsidies, production taxes or subsidies, and carbon taxes. This leaves considerable room for further quantitative analyses of policy measures to limit import dependence in clean energy goods.

Furthermore, the models discussed above analyze settings in which production location and ownership country are identical, hence ignoring that firms from one country may dominate the market in a given industry more or less than implied by the respective country's production share. Aligning them with quantitative models of international trade and multinational production would yield a more nuanced analysis of the aggregate and distributional effects of industrial policies or decoupling (see Arkolakis et al. (2018)).

7. Conclusions and Outlook

In a world increasingly marked by geopolitical tensions, import dependence has come to be considered a threat. It has risen to the top of political agendas and, consequently, a plethora of policies have been proposed to make supply chains more resilient. This concern is of particular importance for clean energy goods, which are central for climate change mitigation and are increasingly regarded as promising sources of future value-added and employment.

However, discussions on how to deal with import dependence for clean energy technologies and critical raw materials often fail to spell out which specific underlying problems are addressed by the proposed policies. This makes it difficult to compare the benefits and costs of different policy options. By relating import dependence to relevant market failures, this paper helps to place the debate on well-established economic foundations.

A better understanding of the underlying problems (and broader geopolitical objectives) is essential when comparing different policies and seeking to justify why certain policy instruments are preferred over others. Where alternative policy options are available and appear equally effective in advancing the desired objective, the least intrusive should take precedence to reduce impacts on international trade. Flexible and cost-effective options, such as traded or tiered import rate quota, should hence be favored over across-the-board trade restrictions.

This paper offers a first conceptual step in that direction. Subsequent research will be needed to better understand the interplay of different market failures and their implications for the appropriate policy mix.

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