❀❀ AOSIS

Logistics and the future: The rise of macrologistics

CrossMark
click for updates

Author:
Jan H. Havenga[1] ⓘ

Affiliation:
[1]Department of Logistics, Stellenbosch University, South Africa

Corresponding author:
Jan Havenga, janh@sun.ac.za

Background: The components of national freight logistics costs are still optimised in isolation, instead of systemic optimisation between logistics and other supply chain elements. The risk is the tragedy of the commons effect, where a positive return for economic activities in isolation could lead to a negative collective result in the long-term. Therefore, there is a need to elevate the systemic view of logistics to the macroeconomic realm.

Objectives: The primary objective of this study was to further the macrologistics discipline through its formal definition and to develop an instrumentation construct to support macroeconomic trade-off analysis. The secondary objective was to apply instrumentation outputs to national-level logistics challenges.

Method: A review of macrologistics was conducted, followed by a discussion on macrologistics instrumentation, which is twofold: a freight-flow model and a related logistics costs model. A disaggregated national input–output table was developed, followed by gravity modelling, to determine freight flows. Logistics cost calculations relate these flows to the costs of fulfilling associated logistics functions.

Results: This review contributes to the developing theory of macrologistics, while the instrumentation outputs improve the systemic understanding of the national freight-flow landscape, enabling informed debate and prioritisation analysis. This systemic view enabled macrologistics proposals to address South Africa's logistics challenges, including proposals regarding a domestic intermodal strategy externality cost internalisation; international trade facilitation; infrastructure investments; and rail branch line revitalisation.

Conclusion: The elevation of logistics to the macroeconomic realm will enable the management of logistics as a national production factor, thereby contributing to reducing national freight logistics costs and improving national competitiveness.

Introduction

The functional-level definition of logistics refers to the forward and reverse flow and storage of goods in the supply chain, from the point of origin to the point of consumption, enabled by financial transactions and information. In the firm-level view, the role of logistics is expanded to an integrative and systemic support function. This role is performed through the application of trade-offs to determine optimal cost levels for the aggregate costs of transport, storage, related inventory carrying charges, and management and administration requirements, with the ultimate goal of conforming to customer requirements (Lummus, Krumwiede & Vokurka 2001; Stock & Lambert 2001).

The concept of a supply chain focus expands the firm-level view of logistics to add the trade-offs between logistics costs and the other cost components of the firm, for example, purchasing, production and marketing costs, to enable the lowest total cost of ownership (Ellram & Siferd 1998). The latter cost focus emerged as the lowest logistics (or transport) costs and might not lead to the lowest total cost of ownership. For example, the cost benefit of bulk purchasing discounts may be negated by higher inventory carrying and storage costs.

Evolutions within the supply chain discipline over the last two decades are taking these trade-offs one step further, that is, to have a value chain view where the cost trade-offs take place between multiple firms' value, creating processes to deliver superior customer value at less cost to the value chain as a whole (Christopher 2005). The implementation is complex and much of the current research (Chakkol, Selviaridis & Finne 2018) shows that success is contingent on improved collaboration, transparency and risk–reward sharing agreements as core components of value chain management.

What emerges from the evolution of the logistics discipline described above is that logistics and supply chain management are typically defined from microeconomic perspectives, optimising firm-level logistics and other supply chain costs. However, the implications for the national economy are that firms and logistics service providers drive optimal logistics solutions within their specific contexts, without cognisance of the broader economic, environmental or social impact. The risk here is what is referred to as the tragedy of the commons, introduced by Hardin's (1968) seminal work, where he uses the example of herdsmen, each acting rationally based on self-interest, exploiting common grazing land by adding as many cattle as possible, until in the long run the carrying capacity of the land is exceeded. A positive return for each single economic actor in isolation, without accounting for the impact on the 'common good', could therefore lead to a negative collective result in the long-term. Only when all stakeholders are held accountable for the full cost of their choices will individual choices, influenced by this cost accountability, aggregate for the greater good.

From a different perspective, logistics on a business level (i.e. microeconomics) aims to reduce the total cost of ownership of supply chains. Ellram (1995, 2002) describes this as the philosophy for understanding all the relevant supply chain-related costs of doing business with a particular supplier for particular goods or services, in order to enable trade-offs between supply chain cost components to identify the lowest total cost option. The concept of the total cost of ownership of economies does not differ from the total cost of ownership on a business level. Production factors on a macroeconomic level, such as natural resources, capital and labour (Lefevre 2016), employed to produce the total output of an economy, that is, the gross domestic product (GDP), should be traded off in the most efficient configuration. The objective here would then be the systemic calculation of all resource costs required for sustainable freight logistics configurations to enable trade-offs against other macroeconomic production factors.

This provides a new perspective in the field of logistics. It requires a contribution of logistics to the national economy akin to that of business logistics, which is to develop systemic measurement tools to describe how different combinations of alternatives can bring about different results. The ultimate objective of this article is to describe the instrumentation required to execute this trade-off analysis on a national level, provide examples and initiate the process of developing a theory of macrologistics. It is also important to note that this is not an alternative term for trade. This systemic approach would be possible if a company does not trade at all and also if a country does not trade at all. It has to do with the interaction between supply and demand on a national level, which is impacted by infrastructure, policy and meso-level industry agglomerations.

Following from this perspective, the primary objective of this article is to further the development of the emerging field of macrologistics through its formal definition and the development of a quantification construct for macrologistics to support macroeconomic trade-off analysis. The secondary objective is to continuously illustrate the feasibility of the instrumentation outputs in addressing national-level logistics challenges.

In the next section, the role of macrologistics in the macroeconomy is defined, followed by a description of the methodology that supports the quantification of macrologistics. In the results section, the model outputs enable a succinct narrative of South Africa's macrologistics landscape, while the discussion section demonstrates how this understanding contributes to macrologistics management successes. Subsequently, global trends on both the supply- and demand-side of logistics are discussed. As these trends mature, it is important to take cognisance of the relevant impacts in the instrumentation process. The concluding remarks summarise the research and highlight next steps.

Macrologistics
A macroeconomic discipline

The term 'macrologistics' is not new in the literature and some perspectives have already been documented, although limited and without a trade-off measurement dimension (which is at the heart of logistics).

Gleissner and Femerling (2013) described macrologistics based on its components, namely the traffic system and infrastructure required to provide transport and warehousing. They expanded the view to what they call 'societal logistics', where the human element is included. Banomyong, Cook and Kent (2008) defined four components, that is, infrastructure, institutional framework, service providers and shippers of goods. An important addition of the latter study is the addition of the institutional framework (or policy) perspective. Skowrońska (2013) also accentuated the policy and infrastructure dimensions of macrologistics and expanded the view towards the integration of peripheral areas, the standardisation of services and technologies and the strengthening of trade and industry. However, none of these studies provide the instrumentation required for logistics to demonstrate the discipline's relevance in the macroeconomic sphere. The objectives of this article advance the position of macrologistics as a macroeconomic discipline.

The backbone of all high-performing systems is management information (Fredendall & Hill 2001). This holds true irrespective of whether the performance of businesses, industries or entire economies is at stake. The macroeconomic imperative for tracking the key components of national logistics costs lies in the fact that a more efficient logistics system is one of the key pillars to support sustainable economic growth. Zaman and Shamsuddin (2017), for example, estimated that the timeliness of logistics has a significant impact on per capita income. Coto-Millán et al. (2016), using Logistics Performance Index (LPI) data, estimated that

every 1% increase in LPI, ceteris paribus, increases domestic technical efficiency by 0.59%.

Yet, out of the 86 development indicators listed in 2014 by the South African Government (Department of Planning, Monitoring and Evaluation 2014), not one refers to freight logistics or the key role it plays in the country's development or economic competitiveness. (Transport infrastructure is listed in an annexure and only lists the kilometre lengths of the South African road and rail network, without any insight into the competitive landscape.) The same holds true for the regular macroeconomic indicators tracked by the South African Reserve Bank and Statistics South Africa.

However, this situation is not unique to South Africa, or even the developing world; globally, the macroeconomic shift towards strategic logistics management is still in its infancy. Tavasszy and De Jong (2014) lament the sluggish development of measurement tools to inform and evaluate freight transport policies, and ascribe this mainly to the failure of viewing transport and logistics as a component of public policy and national competitiveness. The only routine macromeasurement of country-level logistics performance is the World Bank's LPI. The LPI is a biennial worldwide survey of freight logistics operators, providing feedback on the logistics 'friendliness' of the countries in which they operate and those with which they trade, supplemented by quantitative data on the performance of key components of the logistics chain. While the LPI is a valuable benchmarking tool, the LPI measures performance at major international gateways and not logistics connectivity and performance in the domestic economy (World Bank 2016). The LPI is also survey based (Ruamsook 2009) and, moreover, self-assessment based (Su & Ke 2015), which could lead to the fragility of the measurements. Lakshmanan and Anderson (2002) emphasise the need for performance-based research to clearly demonstrate the link between logistics infrastructure investment and economic growth in national economies. They appeal for indicators to inform the development of national logistics strategies and track performance of the macrologistics system against national strategies.

The development and application of measurement tools support the role of macrologistics in the macroeconomy through developing a narrative of the state of a nation's freight transport system and the drivers thereof. This enables the forecasting of freight flows, the exploration of alternative futures, the design of freight policies and systems informed by a chosen future, and the performance assessment of freight systems in meeting its design features (Tavasszy & De Jong 2014).

The question remains why other macroeconomic indicators, such as inflation and interest rates, receive so much attention, when each of these indicators, in isolation, has a smaller cost impact on final products. The reason is that the systemic view of logistics has not yet been transposed to the national economy; currently, the focus is still on optimising national logistics costs components in isolation (e.g. road- or rail transport), instead of looking for savings in systemic interactions between logistics and other supply chain elements. An increased investment, for example, in a port, will attract higher direct port costs, but could decrease the cost of transport, by reducing the unit cost of road transport as a result of faster truck turnaround time and the unit cost of maritime transport through faster ship turnaround times. This could also decrease the inventory carrying cost of inventory in transit by shortening the cash-to-cash cycle. All of these can and should be measured on a national level.

In recent years, a growing number of countries have measured logistics costs as a percentage of GDP, working from the premise that competitive nations will spend less per dollar of GDP output than less-competitive nations. As a result of variable methodological approaches, meaningful comparisons between these measurements are often not possible (Rantasila & Ojala 2015). Furthermore, what is still lacking is the ability to estimate the cost trade-offs between logistics costs elements on a national scale and the resulting impact on the macroeconomy, as well as the impact of macroeconomic events on logistics. The work by Rantasila and Ojala (2015) on the review of extant research in national-level logistics costs measurement is the most comprehensive yet. It is evident from their research that the overarching objective that has been achieved in many countries is the measurement of static logistics costs in order to develop indicators and develop policy. The work is based on more extensive research in Rantasila's (2013) doctoral thesis, which made great progress in this field, but activity-based data that enables flow level trade-offs are not yet present. Solakivi et al. (2018) recently took this work even further, attempting to focus on the measurement of insourced logistics activities on a national level (the difficult portion of national-level cost measurement), but the approach is still survey based and the absence of activity-based data will not enable trade-offs. The application of the freight-flow and logistics costs models described in the methodology section enables an analysis of these trade-offs, which, in turn, enables a definition of macrologistics with the ultimate aim of advancing the understanding of the discipline's macroeconomic role.

For the purposes of this article, the objective of macroeconomic management is therefore defined as engineering the lowest total cost of ownership to the national economy through cost trade-offs between macroeconomic production factors and input costs (including economic, social and environmental costs). The role of macrologistics in macroeconomic management is defined as the estimation of sustainable freight logistics configurations on national and industry levels to enable macroeconomic trade-offs against other production factors. The development of the tools to enable this role is what is referred to as the instrumentation of macrologistics, as described in the next section.

Methodology

The instrumentation of macrologistics

The key driver of the instrumentation of macrologistics is the sufficient disaggregation of the national transportable economy on a spatial and commodity level to enable a detailed analysis of all the core components of the national freight system.

Modelling disaggregated national freight flows

The Freight Demand Model (FDM) is a demand-side model (i.e. it models the demand for freight transport), based on the national input–output table. The FDM estimates the national supply of and demand for commodities in geographical areas and translates these parameters into modal share through gravity modelling for 83 commodities between 372 geographical areas (356 magisterial districts, 8 inland border posts, 7 ocean ports and 1 airport), culminating in a 30-year forecast at 5-year intervals for three scenarios. The methodology was developed in 1998 and Transnet has been sponsoring the application of the methodology since 2006 (Havenga 2013). Once freight flows have been modelled, they are aggregated into typologies to facilitate analysis and recommendations. The primary typology refers to the ring-fenced logistics systems that are by nature mode-monopolistic, with flows typically known, that is, the bulk coal and iron ore exports, pipelines and conveyor belts. The competitive surface freight transport market refers to the corridor, metropolitan and rural freight-flow typologies. The modelled flows are calibrated with industry research and correlated with known freight flows. The model is a hybrid, utilising actual and modelled data, allowing for a more comprehensive analysis of the system under analysis (Islam & Sardar 2007). Correlation with the national input–output table ensures that traffic volumes are not over- or underreported (Liu, Li & Huang 2006). The model has since been applied to all 17 countries of sub-Saharan Africa (King et al. 2016) and India (Simpson, Havenga & Aritua 2016). These applications cover both wide geographical areas and large economies, and it is believed that a wider application could be possible. The possibility of completing models for Vietnam and China is currently being investigated.

Calculating logistics costs

South Africa's logistics cost model measures logistics costs for disaggregated freight flows, as received from the FDM (Havenga 2010). Four direct cost components are calculated, that is, inland transport costs, inventory carrying costs, storage costs, and management and administration costs.

Inland transport costs are calculated as a mode-dependent (rail, road, pipeline) cost per tonne-km. Using actual tariff data for rail and pipelines and a highly detailed road tariff model, the cost per tonne-km is unique for each commodity travelling on each origin–destination pair. The different cost elements of road transport are determined by vehicle type; vehicle types, in turn, are determined by the commodity type, typology and route of travel. The commodity's 'preferred' vehicle type will change with changes in each of these variables. Once the vehicle type and volume are known, the cost elements can be assigned. The core drivers of transport costs, that is, weight in tonnes and distance travelled, form the basis of the approach. Inventory carrying costs take into account the repo rate (the central bank's interest rate) and the average time each commodity is kept in storage. This cost per tonne is unique for each commodity, but is independent of origin–destination pairs. Warehousing costs include all costs associated with keeping a commodity in storage. This includes rental costs, equipment costs, direct labour costs and insurance. It is calculated per tonne, taking into account the average time in storage and the cost per tonne for storage for a specific commodity. The storage cost depends on the packaging type and density of the product. This cost per tonne is unique for each commodity, but is independent of origin–destination pairs. Management and administration costs is cost per tonne, which takes into account the cost of indirect labour, administration and other indirect costs.

An externality cost extension to the logistics costs model was developed to quantify all non-charged costs, which include emissions, accidents, congestion, policing, noise pollution and land use (Havenga 2015).

However, the ultimate goal is to understand the drivers behind these cost elements and the relationship between them on a flow level. This will be showcased through describing the overarching outputs of the model and identifying macrologistics improvement opportunities for South Africa, followed by specific applications of the models to unlock the identified opportunities.

The original cost model was developed for logistics within the borders of the country and therefore stopped at the quay wall. This has since been extended to include port costs as well as the maritime transport leg up to or from foreign ports for South African trade (Havenga, Simpson & Goedhals-Gerber 2017).

Results

South Africa's macrologistics status quo[1]

South Africa is still one of only three countries that consistently measure and publish logistics costs on a national level, the other two being the United States and Finland (Rantasila & Ojala 2015). South Africa's logistics costs totalled R429 billion in 2014, equating to 11.2% of the GDP, compared to North America's 8.6% and Europe's 9.2% in 2014 (Armstrong & Associates, Inc. 2016). It has been proposed to relate logistics costs to only the primary and secondary sectors of the economy as well, by researchers such as Weng and Du (2015). Logistics costs amount to 51.5% of the primary and secondary sectors of the GDP

(i.e. agriculture, mining and manufacturing, also sometimes called the transportable GDP). Transport costs are the dominant contributor to logistics costs, amounting to 57.0% of the total logistics costs in 2014 (compared to the estimated global average of 39.0% [Rodrigue, Comtois & Slack 2009]), followed by inventory carrying costs (15.2%), warehousing (14.6%) and management and administration costs (13.0%).

The demand for land freight transport reached 848m tonne in 2014. The primary economy (agriculture and mining) was responsible for 76% of total volume, but only contributed 44% to the primary and secondary economy (transportable) GDP (i.e. in value terms) added together. In contrast, the secondary sector (manufacturing) made up the remaining 24% of volume, but added 56% value to the primary and secondary (transportable) GDP in value terms. Manufactured commodities are highly densified along the country's two key general freight corridors, namely Gauteng–Cape Town and Gauteng–Durban. The 848m tonnes land freight flows in 2014 translated into 379bn tonne/km. Tonne per kilometre increased by 46%, and tonnes by 17% between 2010 and 2014. If the dedicated ring-fenced transport systems (i.e. the rail export lines, pipelines and conveyor belts) are removed, 272bn tonne/km (or 72.0% of total flows) remain that is classified as general freight, of which approximately half is long-distance corridor freight. Road freight comprised 80% of this long-distance corridor freight and contributed 83% to total transport costs in 2014. Transport externalities added an additional 18% to the already high transport costs; the contribution of non-road modes to these externality costs was negligible. Dense, long-distance flows are ideal candidates for intermodal solutions (Havenga, Simpson & De Bod 2012), which will, in addition to reducing direct logistics costs, also reduce externalities (refer to the section on applications).

The instrumentation of macrologistics has enabled South Africa to identify the following macrologistics challenges:

• The country's logistics costs, as a percentage of GDP and transportable GDP, exceed that of key trading partners.
• The contribution of transport costs to total logistics costs is significant.
• The modal balance on dense, long-distance corridors is untenable.
• The contribution of road transport to general freight transport costs and externality costs is not sustainable.

Various reasons exist for these challenges and some are being addressed through various interventions, albeit often unsuccessfully. Gunasekaran, Patel and McGaughey (2004) strongly emphasise measurement because the role thereof in 'the success of an organisation cannot be overstated because they affect strategic, tactical and operational planning and control'. It can therefore be postulated that these challenges can be better managed by macrologistics measurement and macrologistics management attention.

Discussion
South Africa's macrologistics improvement opportunities

In order to address South Africa's macrologistics challenges, logistics is considered from both a demand-side and a supply-side perspective, that is, how much logistics does the South African economy need, relative to the country's GDP output (demand-side), and how effectively is this provided (supply-side)?

South Africa's logistics demand is disproportionate to the size of the economy. The world requires, for example, about 32 trillion surface freight tonne/km (road and rail) (International Transport Forum 2017) to generate $75 trillion of GDP (World Bank 2017), that is, approximately $2.40 return for every tonne/km provided. The South African GDP amounts to $317bn (World Bank 2017), requiring 379bn surface freight tonne/km, that is, the return is less than $1.00 for every tonne/km provided. South Africa's tonne/km demand is therefore almost three times less competitive than the world average. That is an extraordinary backlog from the outset.

One of the reasons for this is that South Africa is a spatially challenged country. The country has a relatively small economy in relation to a large land mass, with both commodities and production centres far from ports and coastal demand areas (as a result of the location of mining deposits and resulting developments in close proximity). Although passenger transport is outside the scope of logistics, the geographical disparity highlighted in this research, which leads to an inordinate transport demand, will also affect passenger transportation. Even though South Africa's GDP is an insignificant 0.4% of the world economy, the air route between Johannesburg and Cape Town is the 10th busiest air route in the world (Statista 2018; Worldatlas 2017). This is just one indicator of a passenger transport system with a high demand, and massive funding and complex policy issues (Walters 2013).

There are two further challenges on the demand-side. Firstly, the reliance on bulk exports increases the pressure on logistics infrastructure at low returns. This speaks to the need for increased beneficiation (while not negating the importance of service delivery in bulk exports). Secondly, the proliferation of product choice impacts logistics costs through higher inventory levels and transport costs.

On the supply-side of logistics, the country faces a number of challenges. One is the modal imbalance alluded to earlier, where the majority of high-volume, long-distance traffic ideally suited to rail is delivered via road, with significant direct and externality cost implications. The extent of the road freight demand gave rise to a concentrated logistics service provider industry, with the top seven companies owning close to half of the country's outsourced fleet. (On a positive note, the efficiency of these service providers is a large part of

the reason that South Africa outperforms all its partners in the BRICS alliance, i.e. Brazil, Russia, India and China, in the global LPI.)

The road freight transport industry also has an ongoing efficiency drive, focused on improving efficiencies in equipment, driver behaviour, scheduling and planning in order to eliminate empty haul and improve load factors. As part of these initiatives, the Road Transport Management System (RTMS) was launched in 2003 in an attempt to self-regulate South Africa's road freight transport sector (Collings 2009). There have been successes in this regard, such as RTMS-certified organisations reporting a reduction in the number of accidents of between 40.0% and 66.0% over a 5-year period, translating into a decrease in the cost of accidents from 5.0% of revenue to 1.3% of revenue. These results are indicative of what can be achieved; however, substantial efforts are required to raise awareness for increased certification and compliance (Nordengen & Naidoo 2014).

However, the hinterland challenges of high road transport market share remain, partly evidenced through a failing rural road system. The latter is also attributable to the ineffective policy environment, which hampers not only investment in rural road infrastructure but also the revival of rail branch lines.

The policy challenges are pervasive in the freight transport sector. There is a significant gap between the visionary policies developed by the Department of Transport (DoT) over the past two decades and the implementation of those policies. This is evidenced by the persistent macrologistics challenges reported earlier. The essential role of a national government in addressing these macroeconomic challenges is highlighted by successes in, for example, the United Kingdom and Sweden (UNCTAD 2014). One of the key impediments hampering the DoT in executing this role is fragmentation – fragmentation of accountability, of the strategic process (focusing mainly on policy development and not implementation) and of infrastructure investments (through, e.g. various Transnet entities, SANRAL and provinces). The DoT is working on some disparate measures, mainly because of public pressure, such as reducing axle loads on rural roads and banning trucks in peak hours. While the effect of these measures can be estimated with the aid of the models described in this article, the DoT is poorly capacitated to move this forward strategically.

Despite these challenges, significant infrastructure investments in ports, pipelines, railways and long-distance national roads are ongoing. The key here is to ensure that these investment initiatives are aligned with a national strategic vision for South Africa's freight logistics industry to support sustainable economic development. The purpose of the research presented here is, inter alia, to aid the development, endorsement and implementation of such a vision.

The instrumentation of macrologistics
Illustrative examples of developing instruments that could lead to solutions for policy and infrastructure prioritisation

The systemic view provided by the macrologistics instrumentation defined in this article has already enabled specific macrologistics application successes in South Africa, as described below:

- More than half of South Africa's potential intermodal freight moves on the country's two most dense freight corridors. Building three intermodal terminals to connect the three major industrial hubs – Gauteng, Durban and Cape Town – could enable a modal shift to rail, increasing rail densities and thereby reducing logistics costs (including externalities) for the identified intermodal freight flows on these two corridors by two-thirds (Havenga et al. 2012). Policy implementation challenges are hampering successes in this regard.

- Transport externalities add an additional 18% to the already high transport costs. Scenarios indicate that increased returns to rail density as a result of a modal shift could result in a lower total national freight bill, despite the internalisation of all externality costs (Havenga 2015; Havenga & Simpson 2018).

- Research outputs illustrate the advantages of supply chain coordination and the elimination of trade barriers. Reducing delays at South Africa's two major inland border posts could reduce the costs related to these delays by 55%, as a result of reduced buffer stock required at the destination site, reduced costs of carrying inventory and reduced vehicle utilisation losses (Havenga, Van Eeden & Pienaar 2013). Havenga et al. (2017) show that, for international trade, trade documentation costs and induced transport costs because of truck and ship standing times are approximately equal to direct port charges. These costs are at least in part avoidable and can be addressed through improved port efficiencies and collaboration between the ports, industry and the South African Revenue Service.

- The freight-flow model is a key input to inform Transnet's infrastructure investments in rail, ports and pipelines in this century, estimated at R500bn, until 2027 (Njobeni 2016).

- Detailed spatial data analysis points to opportunities for a revival of rail branch lines, which will reduce transport costs and externality charges in rural areas and increase equitable access to the core transport network. The research also expounds the single-network characteristic of South Africa's railroad, based on density requirements and relative to the size of the network (Simpson & Havenga 2010).

- In future, the analysis could play a more definitive role in supporting beneficiation projects in South Africa. The extent of the output data has enabled the development of specific beneficiation scenarios, such as building another petroleum-from-coal conversion plant, increasing steel and automotive production, increasing gas production, investigating new metal beneficiation options and demonstrating the logistics benefits of these initiatives. However, given the current presence of powerful lobbies in the country's political and economic spheres, these initiatives have not yet found traction.

In 2016, the macrologistics instrumentation defined in this article was expanded to India (a project funded by the World Bank). The results have already informed two major infrastructure investments and serves to corroborate the value of a macrologistics perspective. Firstly, the development of a freight village and extended gate for Kolkata port at Balaghar, as part of an integrated corridor design on the Delhi–Kolkata corridor, one of the densest freight corridors in the world. This will decongest cities and highways through the redirection of freight, and serves as a case study to inform integrated corridor design in the rest of India. Initial indications are that logistics costs on the corridor can be halved (Simpson et al. 2016). Secondly, in Varanasi, the model results illustrated that a freight terminal currently being established could capture 39m tonnes of intermodal freight rather than a meagre 1m tonne (Dash 2017).

The next section summarises exciting trends within the supply chain discipline. The potential economic, environmental and social impacts of these trends underscore the importance of the formalisation of macrologistics as a macroeconomic field in its own right.

The future of logistics

An important extension in the logistics discipline could be the solidification of the theory and instrumentation of macrologistics to assist society on a macroeconomic level to make better choices for improved economic, environmental and social outcomes.

Supply-side developments

Supply-side changes will see a relentless drive towards more efficient modes and equipment. Road freight optimisation is continuing unabated (Seitz, Beuttenmüller & Terzidis 2015), but will see a major shift from continuous improvements to disruptive technologies such as driverless trucks and drone delivery (Connolly & Coughlin 2017; Van Meldert & De Boeck 2016), which could reduce logistics costs relative to GDP.

Eventually, the physical Internet could lead to new advances and a new way of tackling large-scale logistics issues. This development, according to Montreuil (2011), is likely because of the fact that it is unsustainable (economically, environmentally and socially) to continue with the current approaches to logistics. The physical Internet is a new concept aiming to redesign the current global logistics system to improve its economic, environmental and social efficiency and sustainability outcomes. The physical Internet will unitise shipments into globally standardised 'packets', just as the electronic Internet does with information, and find faceless, driverless, automatic routes through portals, similar to the services provided by Internet service providers. Beyond the portal, the packet will unitise with others and optimise routes automatically to a final destination, using a combination of efficient routes and

technologies, such as hyperloops. The core enabler of the physical Internet is the use of modular 'black-box' containers, that is, goods themselves that are only handled at the original point of supply and the final point of distribution (Crainic & Montreuil 2016).

In summary, the world might see 'hyperefficiency' in the provision of logistics from both a component and systemic viewpoint. The components of logistics such as vehicles, warehouses and logistics infrastructure are experiencing many continuous improvements, but new technologies such as energy efficiencies, sustainability, driverless trucks, drone delivery and 3D (3-dimentional) printing should lead to major advances. Systemically new integrated delivery systems such as the physical Internet could change the way in which we facilitate storage and delivery.

Demand-side developments

On the demand-side of logistics, first and foremost, the world has to learn about less: less conspicuous consumption, less eating out of season, less choice, less waste. The carbon footprint and waste associated with rampant consumerism are not sustainable. Consumption should focus on seasonal produce, procured as close as possible to the source of production – called the war on choice and the war on globalisation, which might gather steam.

Nash-Hoff (2016) refers to over 300 case studies of companies in the United States that have reshored parts of their business between 2010 and 2016, amounting to 100 000 manufacturing jobs returning to the United States. The Reshoring Initiative (cited in Nash-Hoff 2016), an organisation promoting the benefit of reshoring for companies in the United States, estimates that a quarter of offshored manufacturing would return to the United States if the total cost of ownership is used in supply chain calculations. Caterpillar, General Electric, Ford, Apple, Coleman and Master Lock all shifted some manufacturing operations back to the United States (Moneynews 2013; Plumer 2013). Gärtner (2012) cites some European examples. The key driving forces for these reshoring initiatives are cited to be increasing wages in China, higher international transport costs and quality challenges. Proximity to markets also allows responsiveness to local needs, while the utilisation of available local production capacity is favoured in a challenging global economic environment. Other developments that will reduce the demand for logistics are recycling at source and additive manufacturing (or 3D printing) (Attaran 2017).

In future, as a result of these demand-side factors, a decoupling of logistics and GDP is expected, that is, the relationship between GDP and logistics might become more tenuous and the input of logistics in creating GDP should naturally decline. Klaus (2009) conducted an analysis of the relationship between logistics spending and GDP. He confirmed the role of specialisation, that is, as economies grow, specialisation increases, time and place disparity worsens and logistics spending increases. However, he did

find an indication of maturity in highly developed countries where the role of logistics as a facilitator of growth might decline. Klaus observed that global integration is reaching a limit for these economies and predicts stagnation, or even decline, in the role of logistics, as the need for industrial distribution activities will not grow further. The 'march' of material logistics may come to a halt (Klaus 2009).

Van den Bergh and Lewer (2007) discuss the conflict between Robertson's claim that trade is an 'engine of growth' and Kravis's qualification that trade is a 'handmaiden of growth'; Robertson's observation was from 1931 and Kravis's from 1970. In the next 40-year wave (the current time period), new research might indicate that trade is not necessarily conducive to growth. In fact, growth itself might be redefined.

In summary, logistics, systemically, satisfies human consumption needs, but other than energy, water and other natural resources, a focus to reduce the demand for logistics is not always apparent. This might also be because of a lack of macrologistics perspective. The world needs to rethink global trade, hyperspecialisation, waste and choice and the effect that it has on the demand for logistics, and change behaviours that could lead to the reduction of the demand for logistics.

This leads to the question about the success of GDP as a measure of well-being as, even in the logistics discipline, the performance of logistics on a national level is expressed in relation to GDP.

Intrinsic questions about gross domestic product

The balanced view of sustainable development first proposed by the World Commission on Environment and Development (United Nations 1987) has been generally accepted as a valid construct. This view calls for an equal balance between economic growth, social development and environmental protection. Sustainable Aotearoa New Zealand (2009) (a national sustainability research organisation) questions the balanced version of this 'triple bottom line' model. The organisation laments the fact that GDP growth still receives priority and proposes the 'strong' model where GDP growth is seen to be less important than environmental protection and social development. In fact, GDP growth as such is called into question.

The concerns relating to an unchecked global economic growth paradigm were reintroduced into contemporary debate in the early 1970s by the global think tank the Club of Rome (Meadows et al. 1972). They modelled the quantitative restraints on exponential growth, concluding that a business-as-usual growth model would lead to environmental and subsequent economic collapse within a century. Despite criticisms, the model held up well to actual data between 1970 and 2000, confirming the necessity of an inversion in consumptive behaviour to within

planetary limits (Turner 2008). In this century, the convergence of a number of factors, pertinently natural resource depletion, ecological instability and systemic financial and monetary failures, confirmed this view (Guttal 2012; Heinberg 2011).

Demaria et al. (2013:209) define degrowth as 'a democratically led redistributive downscaling of production and consumption in industrialised countries as a means to achieve environmental sustainability, social justice and well-being'. Daly and Posner (2011) summarised the 'case against GDP' in terms of the three pillars of sustainability. In growth terms, GDP does not distinguish between speculative gains and real economic value and does not measure non-market activities that contribute to growth. In social terms, GDP does not measure growth distribution at a household level; it measures quantity and not quality and does not distinguish between 'positive' welfare spending and 'defensive' spending. Social well-being indicators such as poverty, literacy and life expectancy are mostly excluded, while sustainability issues are also largely ignored.

Alternative indicators such as the 'genuine progress indicator' (GPI) have been proposed. Gross domestic product measures current production, while the GPI aims to measure the economic welfare generated by economic activity, essentially 'counting the depreciation of community capital as an economic cost' (Kubiszewski et al. 2013:57). The Gini coefficient that exists should be used more as a well-being index, but even though Barro's research (1999) proved that inequality in developing countries retards growth, inequality is seldom considered in growth measurements for any country.

These developments will be followed with keen interest to inform advancements in the macrologistics definition and instrumentation described in this article.

Conclusion

The primary objective of this article is to further the development of the emerging field of macrologistics through its formal definition and the development of a quantification construct for macrologistics to support macroeconomic trade-off analysis. The secondary objective is to continuously illustrate the feasibility of the instrumentation outputs in addressing national-level logistics challenges.

The aggregate outputs of the instrumentation construct improve the understanding of the freight-flow landscape and enable informed debate and prioritisation analysis. Results show that South Africa's macrologistics challenges persist and this could be for various reasons. It could be that the instrumentation of macrologistics, which was illustrated in this research, could make a contribution to providing a more macrologistics management attention approach. The intention of this work is to support the macroeconomic formalisation of logistics to assist with the resolution of these challenges. Other initiatives flow from this:

- To work with industry and government to aid the development of systemic and critical thinking skills at high school level in order to create the skills required for macrologistics management.
- To continue endeavours to include a systemic view of freight logistics – that is, macrologistics – in the development indicators of the South African Government.
- The instrumentation of macrologistics (in terms of freight-flow modelling) has already been expanded to all 17 countries of sub-Saharan Africa. The intent is to, in the near future, apply the model outputs to solve some of the country-level macrologistics challenges in sub-Saharan Africa, as has been done in India.

Acknowledgements

References

Armstrong & Associates, Inc., 2016, *Global 3PL market size estimates*, viewed 24 March 2017, from https://www.3plogistics.com/3PLmarketGlobal.htm

Attaran, M., 2017, 'Additive manufacturing: The most promising technology to alter the supply chain and logistics', *Journal of Service Science and Management* 10(3), 189–205. https://doi.org/10.4236/jssm.2017.103017

Banomyong, R., Cook, P. & Kent, P., 2008, 'Formulating regional logistics development policy: The case of ASEAN', *International Journal of Logistics Research & Applications* 11(5), 359–379. https://doi.org/10.1080/13675560802389114

Barro, R.J., 1999, *Inequality, growth and investment*, NBER Working Paper Series, National Bureau of Economic Research, viewed 01 November 2017, from http://www.nber.org/papers/w7038.pdf

Chakkol, M., Selviaridis, K. & Finne, M., 2018, 'The governance of collaboration in complex projects', *International Journal of Operations & Production Management* 38(4), 997–1019. https://doi.org/10.1108/IJOPM-11-2017-0717

Christopher, M., 2005, *Logistics and supply chain management: Creating value-adding networks*, 3rd edn., Pearson Education Limited, Edinburgh Gate, Essex.

Collings, P., 2009, 'Optimisation is a reality – RTMS at work in sugar and coal transport', *Fleetwatch*, October, viewed 28 June 2017, from http://www.fleetwatch.co.za/magazines/Oct2009/28-Optimisation%20is%20a%20reality.htm

Connolly, T. & Coughlin, K., 2017, 'Achieving alignment in an age of disruptive velocity', *People & Strategy* 40(2), 20–26.

Coto-Millán, P., Fernández, X.L., Pesquera, M.Á. & Agüeros, M., 2016, 'Impact of logistics on technical efficiency of world production (2007–2012)', *Networks and Spatial Economics* 16(4), 981–995. https://doi.org/10.1007/s11067-015-9306-6

Crainic, T.G. & Montreuil, B., 2016, 'Physical internet enabled hyperconnected city logistics', *Transportation Research Procedia* 12, 383–398. https://doi.org/10.1016/j.trpro.2016.02.074

Daly, L. & Posner, S., 2011, *Beyond GDP: New measures for a new economy*, Dēmos, New York.

Dash, D.K., 2017, 'Varanasi to get India's 1st freight village', *The Times of India*, 01 June, viewed 26 June 2017, from http://timesofindia.indiatimes.com/india/varanasi-to-get-indias-1st-freight-village/articleshow/58935963.cms

Demaria, F., Schneider, F., Sekulova, F. & Martinez-Alier, J., 2013, 'What is degrowth? From an activist slogan to a social movement', *Environmental Values* 22(2), 191–215. https://doi.org/10.3197/096327113X13581561725194

Department of Planning, Monitoring and Evaluation, 2014, *Development indicators 2014*, viewed 23 June 2017, from http://www.dpme.gov.za/publications/Reports%20and%20Other%20Information%20Products/Development%20Indicators%202014.pdf

Ellram, L.M., 1995, 'Total cost of ownership: An analysis approach for purchasing', *International Journal of Physical Distribution & Logistics Management* 25(8), 4–23. https://doi.org/10.1108/09600039510099928

Ellram, L.M., 2002, 'Total cost of ownership', in D. Hahn & L. Kaufmann (eds.), pp. 659–671, *Handbuch Industrielles Beschaffungsmanagement*, Gabler Verlag, Wiesbaden, Germany.

Ellram, L.M. & Siferd, S.P., 1998, 'Total cost of ownership: A key concept in strategic cost management decisions', *Journal of Business Logistics* 19(1), 55–84.

Fredendall, L.D. & Hill, E., 2001, *Basics of supply chain management*, The St. Lucie Press, Boca Raton, FL.

Gärtner, M., 2012, 'Erste Firmen blasen zum China-Rückzug', *Manager Magazin Online*, 01 October, viewed 28 June 2017, from www.manager-magazin.de/politik/weltwirtschaft/0,2828,807918,00.html

Gleissner, H. & Femerling, J.C., 2013, *Logistics – Basics, exercise, case studies*, Springer, Cham, Switzerland.

Gunasekaran, A., Patel, C. & McGaughey, R.E., 2004, 'A framework for supply chain performance measurement', *International Journal of Production Economics* 87(3), 333–347. https://doi.org/10.1016/j.ijpe.2003.08.003

Guttal, S., 2012, 'The urgent need for a paradigm shift', *Forum for Development Studies* 39(1), 125–130. https://doi.org/10.1080/08039410.2011.647884

Hardin, G., 1968, 'The tragedy of the commons', *Science New Series* 162(3859), 1243–1248.

Havenga, J.H., 2010, 'Logistics costs in South Africa: The case for macroeconomic measurement', *South African Journal of Economics* 78(4), 460–478. https://doi.org/10.1111/j.1813-6982.2010.01252.x

Havenga, J.H., 2013, 'The importance of disaggregated freight flow forecasts to inform transport infrastructure investments', *Journal of Transport and Supply Chain Management* 7(1), 1–7. https://doi.org/10.4102/jtscm.v7i1.106

Havenga, J.H., 2015, 'Macrologistics and externality cost trends in South Africa: Underscoring the sustainability imperative', *International Journal of Logistics Research and Applications* 18(2), 118–139. https://doi.org/10.1080/13675567.2015.1015509

Havenga, J.H. & Simpson, Z.P., 2018, 'Freight logistics' contribution to sustainability: Systemic measurement facilitates behavioural change', *Transportation Research Part D: Transport and Environment* 58, 320–331, https://doi.org/10.1016/j.trd.2016.08.035

Havenga, J.H., Simpson, Z.P. & De Bod, A., 2012, 'South Africa's domestic intermodal imperative', *Research in Transportation Business & Management* 5, 38–47. https://doi.org/10.1016/j.rtbm.2012.11.006

Havenga, J.H., Simpson, Z.P. & Goedhals-Gerber, L., 2017, 'International trade logistics costs in South Africa: Informing the port reform agenda', *Research in Transportation Business & Management* 22, 263–275. https://doi.org/10.1016/j.rtbm.2016.08.006

Havenga, J.H., Simpson, Z.P., King, D., de Bod, A. & Braun, M., 2016, *Logistics Barometer South Africa 2016*, Stellenbosch University, viewed 18 April 2018 from https://www.sun.ac.za/english/faculty/economy/logistics/Documents/Logistics%20Barometer/Logistics%20Barometer%202016%20Report.pdf

Havenga, J.H., Van Eeden, J. & Pienaar, W.J., 2013, 'Supply chain cost improvement opportunities through streamlining cross-border operations', *Risk Governance & Control: Financial Markets & Institutions* 3(3), 28–34. https://doi.org/10.22495/rgcv3i3art3

Heinberg, R., 2011, *The end of growth: Adapting to our new economic reality*, New Society, Gabriola Island, BC.

International Transport Forum, 2017, *ITF Transport Outlook 2017*, OECD Publishing, Paris.

Islam, N. & Sardar, M.N., 2007, 'Economy-wide modelling methods for logistics and supply chain systems', in *Proceedings of the 2nd International Conference on Operations and Supply Chain Management*, May 18–20, Bangkok, viewed 02 May 2018 from http://eprints.utcc.ac.th/2151/

King, D.J., Simpson, Z.P., Havenga, J.H., Lanz, E.J. & Swarts, S.J., 2016, 'Freight demand modelling for Southern Africa', in *NOFOMA 2016 – Proceedings of the 28th annual Nordic Logistics Research Network Conference*, Turku School of Economics, Turku, Finland, June 9–10, pp. 289–306.

Klaus, P., 2009, 'Logistics research: A 50 years' march of ideas', *Logistics Research* 1, 53–65. https://doi.org/10.1007/s12159-008-0009-y

Kubiszewski, I., Costanza, R., Franco, C., Lawn, P., Talberth, J., Jackson, T. et al., 2013, 'Beyond GDP: Measuring and achieving global genuine progress', *Ecological Economics* 93, 57–68. https://doi.org/10.1016/j.ecolecon.2013.04.019

Lakshmanan, T.R. & Anderson, W.P., 2002, *Transportation infrastructure, freight services and economic growth: A synopsis of a white paper*, Federal Highway Administration, US Department of Transportation, Washington, DC.

Lefevre, J., 2016, 'Hybridization challenges in energy-economy integrated models and representation of the low carbon transition: An application to the Brazilian case', PhD thesis, University of Paris-Saclay, viewed 21 November 2017, from http://www2.centre-cired.fr/IMG/pdf/thesis_jlefevre.pdf

Liu, W., Li, W. & Huang, W., 2006, 'Analysis of the dynamic relation between logistics development and GDP growth in China', in *2006 IEEE International Conference on Service Operations and Logistics, and Informatics*, Shanghai, June 21–23, pp. 153–157.

Lummus, R.R., Krumwiede, D.W. & Vokurka, R.J., 2001, 'The relationship of logistics to supply chain management: Developing a common industry definition', *Industrial Management & Data Systems* 101(8), 426–432. https://doi.org/10.1108/02635570110406730

Meadows, D.H., Meadows, D.L., Randers, J. & Behrens, W.W., 1972, *The limits to growth, 1972. A report for the Club of Rome's project on the predicament of mankind*, Universe Books, New York, NY.

Moneynews, 2013, *Made in America label stages comeback at US stores*, viewed 28 June 2017, from https://www.moneynews.com/Economy/America-manufacturing-advantage-imports/2013/05/03/id/502731

Montreuil, B., 2011, 'Toward a physical internet: Meeting the global logistics sustainability grand challenge', *Logistics Research* 3(2–3), 71–87. https://doi.org/10.1007/s12159-011-0045-x

Nash-Hoff, M., 2016, 'Is reshoring increasing or declining?', *Industry Week*, 22 January, viewed 28 June 2016, from http://www.industryweek.com/global-economy/reshoring-increasing-or-declining

Njobeni, S., 2016, 'Commodities slump puts Transnet off rail', *Business Report*, 28 June, viewed 23 June 2017, from http://www.iol.co.za/business-report/companies/commodities-slump-puts-transnet-off-rail-2039196

Nordengen, P.A. & Naidoo, O.J., 2014, 'Evaluation of the Road Transport Management System, a self-regulation initiative in heavy vehicle transport in South Africa', Paper presented at the Transport Research Arena, 14–17 April, Paris.

Plumer, B., 2013, 'Is US manufacturing making a comeback – Or is it just hype?', *The Washington Post*, 01 May, viewed 28 June 2017, from https://www.washingtonpost.com/blogs/wonkblog/wp/2013/05/01/is-u-s-manufacturing-set-for-a-comeback-or-is-it-all-hype/

Rantasila, K., 2013, *Measuring logistics costs – Designing a generic model for assessing macro logistics costs in a global context with empirical evidence from the manufacturing and trading industries*, Series A, Publications of Turku School of Economics, Helsinki.

Rantasila, K. & Ojala, L., 2015, 'National-level logistics costs: An overview of extant research', *International Journal of Logistics Research and Applications* 18(4), 313–324. https://doi.org/10.1080/13675567.2015.1016413

Rodrigue, J.P., Comtois, C. & Slack, B., 2009, *The geography of transport systems*, 2nd edn., Routledge, New York, NY.

Ruamsook, K., 2009, 'Sourcing from low-cost countries: Identifying sourcing issues and prioritizing impacts on logistics performance', *International Journal of Logistics Management* 20(1), 79–96. https://doi.org/10.1108/09574090910954855

Seitz, C.S., Beuttenmüller, O. & Terzidis, O., 2015, 'Organizational adoption behaviour of CO_2-saving power train technologies: An empirical study on the German heavy-duty vehicles market', *Transportation Research Part A: Policy and Practice* 80, 247–262. https://doi.org/10.1016/j.tra.2015.08.002

Simpson, Z. & Havenga, J.H., 2010, 'Revitalisation of branch lines in South Africa: A long-term view for sustainability', *Journal of Transport and Supply Chain Management* 4(1), 243–254. https://doi.org/10.4102/jtscm.v4i1.70

Simpson, Z.P., Havenga, J.H. & Aritua, B., 2016, 'Freight-flow modelling and macrologistics: Customising the southern African model for application in India', Paper presented at the 21st Annual Logistics Research Network, 7–9 September, University of Hull, Kingston upon Hull.

Skowrońska, A., 2013, 'Macrologistics in the policy of the European Union', *Gospodarka Materialowa* 4, 2–9.

Solakivi, T., Ojala, L., Lorentz, H., Töyli, J. & Laari, S., 2018, 'Estimating the size of the national logistics market: A method to include both market-based demand and in-house services', *International Journal of Physical Distribution & Logistics Management*. https://doi.org/10.1108/IJPDLM-01-2018-0032

Statista, 2018, *The world's busiest air routes*, viewed 02 April 2018, from https://www.statista.com/chart/12598/the-worlds-busiest-air-routes/

Stock, J.R. & Lambert, D.M., 2001, *Strategic logistics management*, 4th edn., McGraw-Hill Higher Education, Singapore.

Su, S. & Ke, J., 2015, 'National logistics performance benchmarking for trade connectivity: An innovative approach', Conference paper, viewed 31 October 2017, from https://www.researchgate.net/profile/Jian-yu_Ke/publication/281714450_National_Logistics_Performance_Benchmarking_for_Trade_Connectivity_-_An_Innovative_Approach_Using_World_Bank_Logistics_Performance_Index_Database/links/55f58de108ae7a10cf8b6b1b.pdf

Sustainable Aotearoa New Zealand, 2009, *Strong sustainability for New Zealand: Principles and scenarios*, Nakedize, Auckland.

Tavasszy, L. & De Jong, G., 2014, 'Introduction', in L. Tavasszy & G. de Jong (eds.), *Modelling freight transport*, pp. 1–12, Elsevier, Amsterdam.

Turner, G.M., 2008, 'A comparison of the limits to growth with 30 years of reality', *Global Environmental Change* 18(3), 397–411. https://doi.org/10.1016/j.gloenvcha.2008.05.001

UNCTAD, 2014, *National trade facilitation bodies in the world*, viewed 22 June 2017, from http://unctad.org/en/PublicationsLibrary/dtltlb2014d1_en.pdf

United Nations, 1987, *Report of the world commission on environment and development: Our common future*, viewed 28 June 2017, from http://www.un-documents.net/our-common-future.pdf

Van den Bergh, H. & Lewer, J.J., 2007, *International trade and economic growth*, ME Sharpe, Armonk, NY.

Van Meldert, B. & De Boeck, L., 2016, *Introducing autonomous vehicles in logistics: A review from a broad perspective*, Facility of Economics and Business, KU Leuven, viewed 25 June 2017, from https://lirias.kuleuven.be/bitstream/123456789/543558/1/KBI_1618.pdf

Walters, J., 2013, 'Overview of public transport policy developments in South Africa', *Research in Transportation Economics* 39(1), 34–45. https://doi.org/10.1016/j.retrec.2012.05.021

Weng, X. & Du, X., 2015, 'Restudy on macro logistics cost of China', *Modern Economy* 6(1), 1173–1179. https://doi.org/10.4236/me.2015.611111

Worldatlas, 2017, *Busiest air routes in the world*, viewed 01 November 2017, from http://www.worldatlas.com/articles/busiest-air-routes-in-the-world.html

World Bank, 2016, *Connecting to compete 2016 – Trade logistics in the global economy. The Logistics Performance Index and its indicators*, viewed 01 March 2017, from https://openknowledge.worldbank.org/bitstream/handle/10986/24598/Connecting0to00n0the0global0economy.pdf

World Bank, 2017, *GDP (current US$)*, viewed 15 August 2017, from http://data.worldbank.org/indicator/NY.GDP.MKTP.CD?end=2015

Zaman, K. & Shamsuddin, S., 2017, 'Green logistics and national scale economic indicators: Evidence from a panel of selected European countries', *Journal of Cleaner Production* 143, 51–63. https://doi.org/10.1016/j.jclepro.2016.12.150