Operationalizing a Model of
Landside Access and Seaport Container Activity

by

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B.A., International Relations
University of Pennsylvania, 1988

Submitted to the Department of Urban Studies and Planning and
the Center for Transportation Studies
in Partial Fulfillment of the Requirements for the Degrees of

Master of City Planning

and

Master of Science in Transportation

at the
Massachusetts Institute of Technology
February 1996

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ABSTRACT

Seaports are important to many areas of public policy, including the economy, national security, regional equity, and the environment. In particular, ports have potentially critical impacts on the near and distant hinterland areas to which they facilitate or constrain trade. The amount of containerized cargo handled is often considered a broad measure of a port's efficiency and effectiveness in serving these areas, and therefore also in acnieving broader public policy goals.

Landside access between ports and hinterland areas is frequently a central factor in ports' competition for cargo. Accessibility issues take a variety of forms, with geographic proximity and physical transportation access to hinterland markets usually considered the most important. While there is a consensus on the significance of access in general, conclusions regarding the importance of specific forms of landside access vary greatly from port to port. And while large benefits from access improvement projects are possible, many of these investments are very costly. Thus, there is a need for methodologies to determine where and in what form access improvements are most worthwhile.

Existing studies largely rely on direct microeconomic, market survey, or qualitative case study analysis of a limited number of ports. Such methodologies are appropriate for making individual investment decisions, but their results rarely can be applied to more than a very few ports. International organizations, national governments, and even port authorities share an interest in the broader context of how accessibility to hinterlands affects seaports' cargo activity, and the relative merit of potential investments in landside access. This thesis directly examines the general relationship between landside access to hinterland markets and seaport container activity. In particular, it tries to provide a reasonable level of explanation of container throughput utilizing only a few key economic, demographic, and transport access variables. Statistical methodologies are utilized for the analysis, thus allowing more generalizable conclusions than previous research.

Data on seaport activity, population, the economy, and landside access were collected for 99 seaports in the Western Hemisphere and their hinterlands, with a full data set available for 49 of these ports. The data were analyzed using both descriptive

statistics and multiple regression methodologies. Direct comparisons of statistical attributes of the port data were conducted on the entire sample and on a variety of cohorts. These attributes confirmed that larger ports are likely to have good rail and double-stack access, with rail's mode share, the share of long-distance container moves, and subjective ratings of rail and double-stack access substantially better at larger than at smaller ports. This analysis also showed that a large local metropolitan market (20-mile radius) is more likely to be associated with a busy port, while a large trucking market (400-mile radius) is almost as likely to be present near a small as a large port. The objective and subjective indicators of the quality of regional trucking access showed surprisingly little difference between large ports and small ports.

Regression models were developed relating seaport activity to hinterland economic activity, population, and landside access measures. Model specifications using the larger data set explained up to 62% of the variation in container activity using only location and proximity to markets (geographic, demographic, and economic variables). Additionally including landside transport access variables explained up to 74% of the variation in the smaller, more comprehensive data subset. A large, local metropolitan area and good rail access to large, distant markets were found to be the most consistently important factors in determining seaport container activity. Although other elements of access also displayed results in line with expectations, their impacts were not as strong nor as statistically significant. Most specifications overestimated the activity at smaller ports and underestimated the activity at many large ports, possibly indicating a very significant role for economies of scale, in both vessel and port operations, that was not directly captured in the model. This was confirmed by a variety of regression diagnostics. There is always some danger of data unreliability in using survey results when respondents are giving subjective ratings of themselves. Finally, a high degree of multicollinearity between many of the explanatory variables proved somewhat problematic, and indicates that subsequent statistical analysis will require very comprehensive data collection if more precise results are to be generated.

The demonstrated relative importance of proximity to different hinterland markets provides some insights regarding the long-term viability and potential for traffic at container ports. These results may prove to be of use to national governments and international organizations in their port and maritime policy and investment decision-making. Ocean carriers may be influenced regarding load centering and long-term terminal leases. And individual port authorities may gain a broader perspective on how their long-term strategy may be influenced by market accessibility.

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ACKNOWLEDGMENTS

I would like to take this opportunity to thank my advisors Carl Martland and Qing Shen. They challenged me to rethink both small points and large issues, and this work is tremendously improved because of their advice and support. The backgrounds they have and perspectives they brought, different from both one another and myself, created a team that complemented one another very well in providing me guidance. Their flexibility, patience, and encouragement were instrumental to overcoming the difficulties of trying to tele-complete a thesis.

Hank Marcus also provided valuable insights from the formative to the concluding stages of this work, and extended warm support throughout my years at MIT. I would also like to thank the American Association of Port Authorities and U.S. Maritime Administration for their provision of data that saved me many weeks of additional effort. Sergio Fernandes and Adriana Bernardino were especially helpful in providing translations of the surveys, greatly facilitating my international efforts to collect data. Of course, numerous ports and carriers were the source of most of the raw data, and this work would not have been possible without their enthusiastic response to my questionnaire. Anne Aylward, Monika Mantilla, and Jeffrey Monroe made extra efforts to provide data and advice.

The faculty and staff at MIT have been tremendous in their support and in making my years in Cambridge a privileged time. Nigel Wilson is one of the finest persons I know at listening and giving sound, candid advice. Karen Polenske and Joe Sussman are masters at constructively motivating the best effort from their students, but I am even more thankful for the personal support and advice they gave. David Bernstein, Ralph Gakenheimer, Fred Salvucci, and Paul Smoke also stood out for their special insights in lectures and seminars, as well as their extra efforts outside of the classroom. Lisa Magnano Bleheen is always amazing, and Peter, Karen, MaryGrace, Tim, Cynthia, Sandy, Brenda, and Nancy joyfully helped me out of many jams.

In four Septembers at MIT I benefited from the scholarship and camaraderie of many more students and colleagues than I can name here. However, I especially value the friendship and special moments I shared with Star Chang, Trekkie Roth, Rrr-rrr Shaw, Stunning Sriver, Bull Turk, and Xword Wilson. Geoffrey, Pollo Loco, IceStorm, JDeck, Daniel Rz., Caholio, JT, Texas, Shendingo, Dutt, Chris, Leech, Scooter, LamJim, Joan, and Oki were also great friends and valued companions, as were many others.

My parents instilled in me everything that let me accomplish all I ever have at MIT and elsewhere. I could have no better guides, models, or friends.

Jenny has been a beacon of support, warmth, and encouragement leading me through Cambridge and Washington. I look forward to sharing her light for many, many years.

This thesis is dedicated to all the wonderful goats I meet. Y'all know who you are.

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CHAPTER I. INTRODUCTION

Ports are important elements of public infrastructure, serving to encourage or constrain economic development and growth. Ports also can play a significant role in environmental, defense, distributional and other public policy issues. Improving access to markets frequently contributes to the efficiency and growth of ports, and thus is of general public benefit. However, there has been increasing debate regarding to what extent improving landside access is an investment providing net economic benefits, with the conclusions varying greatly from port to port. Thus, infrastructure expenditure for seaports and seaport access is an important public policy question that involves balancing costly, fixed investments against heterogeneous long-term benefits that are difficult to estimate.

Before getting into the estimation method that this thesis utilizes, further background first is given regarding the importance of ports and landside access, and thus the motivation for a public policy interest in conducting such an estimation.

This chapter develops the rationale behind the importance of ports and their role in our society and economy. It also describes the theoretical and perceived importance of landside access to port efficiency and growth. In particular, this chapter presents ports in terms of their economic, distributional, defense, and other roles. It then describes the role of landside access to ports and strategies for improving this access, providing a cursory background for readers unfamiliar with port and access issues. Finally the appropriateness and motivation for examining ports from a public policy perspective is given.

I.A. SIGNIFICANCE OF SEAPORTS AND ACCESS

> *The* raison d'etre *of a port is to provide an appropriate and efficient method of integrating land and maritime transport systems serving the economies of hinterlands and forelands.*[1]

There has been a substantial amount of attention, mostly quite recent, focused on seaport access as a rewarding area for public investment. Improved port access has been touted as improving a port's competitiveness and benefiting the local, regional and national economies. As seen in the above quote, some have

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1 Hoyle, p. 143.

gone so far as to define a port purely as a means (to broader economic prosperity) and not an (profit-making) end unto itself. Furthermore, it is significant that Hoyle places land transport and the hinterlands (or distant hinterlands) before the traditional vision of a port serving maritime and forelands (or nearby hinterlands) interests.

Ports facilitate trade to inland locations as near as the same city and as far as across the continent. The inland areas to which a port does or potentially could provide service are referred to as hinterlands. Because of the size and diversity of hinterlands, it is often necessary to create some form of typology of hinterland areas in order to clarify discussion. The size of the hinterland, its distance from the seaport and the degree or quality of access between port and hinterland are perhaps the most important characteristics for describing a port's hinterland areas.

A number of explicit benefits can be enumerated for increasing seaport access to the hinterland. The direct benefits of access improvements are best characterized by savings in transport costs, while indirect benefits accrue through a variety of means; application of either varies with the beneficiary. From the port owner's and/or operator's perspective, port container facilities are able to attract cargo better, and thus to increase revenues. Increased use of port facilities and local freight terminals aids efficiency through the greater economies of scale that characterize these facilities; this may benefit both facility operators and consumers. From a broader perspective, both the direct and indirect transport cost savings from access improvements benefit consumers and businesses as a whole by lowering prices and facilitating trade. For society, improved access also creates both additional transportation revenue and jobs, with corresponding social and economic benefits. Of course, one must be careful in tallying these indirect benefits, because any existing cargo attracted from other ports is merely a transfer of benefits rather than an aggregate gain in general welfare.

Through enhanced access, both international and domestic products are able to be shipped to and from the port's region at a lower cost, and hence consumers and firms face lower prices for goods. In many cases, access improvements can not only lower direct transport costs, but also lower transport time and logistics costs for products, thus augmenting the savings. Additionally, the accrued savings can be used for alternative purchases or investment, which stimulate additional direct, indirect, and induced economic benefits since they are spent in the local economy rather than on transportation costs for goods from other nations or regions.

The availability and efficiency of seaports has long been thought to be an important element of international trade, which itself has frequently been considered a critical tool for economic development. A variety of theories exist regarding the potential for inducing economic activity and/or development through investments in transportation infrastructure. In both industrialized and less developed countries, many decision-makers believe that international trade is an important factor in economic growth, and that facilitating port activity can significantly benefit international trade. Other economic issues include employment, productivity and efficiency, as well as transport capacity constraints. Ports also provide economic benefits in terms of fomenting both intersectoral and interregional competition, as well as otherwise influencing economic diversity and the spatial distribution of activity.

In addition to economic issues, ports can be critical to a number of other public policy areas. Environmental issues can be both directly and indirectly impacted by the development of seaports. For example, mode shifts away from air and highway and toward rail and waterborne commerce provide benefits in both energy efficiency and emissions reductions. Seaports are often crucial to national defense, perhaps more importantly as critical links in international logistics networks than as explicit military facilities. Statutory requirements frequently impact the relative, and even absolute, status of ports. Finally, ports are frequently important symbols of cities and regions, lending status and an image to many of the world's great cities.

Despite the benefits summarized above, the best possible access to seaport facilities can rarely be financially justified. For example, at smaller ports the marginal costs of providing double-stack clearance or on-dock rail spurs often far exceeds their incremental benefits. On-dock terminals frequently require acquisition of substantial parcels of expensive land for small extra benefits. The costs of redundant rights-of-way and terminals may not be justified by gains from increased intra-sectoral rail competition, especially if there is the ability to negotiate long-term guaranteed rail rates or track access rights in exchange for public investment in infrastructure. Similar concerns are raised since larger capital projects may have decreasing returns on investment. Many leading industry analysts, including principals at Temple, Barker & Sloane, Inc. and Booz Allen & Hamilton (in a front page banner headline in the *Journal of Commerce*) have cautioned against on-dock rail as being a possible overinvestment for U.S. East Coast ports, for example. The gist of the arguments is that the large capital investments needed for on-dock terminals do not pay off except under special circumstances.

I.B. PUBLIC POLICY INTEREST IN SEAPORTS AND ACCESS

> *In an era dominated by laissez faire thinking, public infrastructure investment is one of those rare activities where government has been criticized for doing too little instead of too much.*[2]

The view of infrastructure as an appropriate area for public investment is especially true for landside access to seaports, an area for which public officials perceive as much need as private citizens do for pothole repair. There are undisputedly some benefits to improving physical access to seaports; but high costs often make achieving enhanced access a questionable use of funds, and there are often alternative means of increasing port activity. Therefore, the questions that ports, governments and other interested parties want to address are the means by which and extent to which access should be improved. By examining the interaction between a port and its hinterland markets, one can begin to answer these questions.

The usually dominant role of government in seaport ownership, control, or operation and the public nature of many port costs, benefits, and externalities has meant that questions of investment in port access usually fall into the realm of public policy debate. Government expenditures on port infrastructure and landside access continue to be a common theme of efforts to achieve trade, economic, and other policy objectives.[3] Although a large proportion of terminal operations are privately run as concessions or leased properties, local, state, national, or parastatal ownership of port facilities remains the norm. So even with the increasing privatization of ports, the importance of improving port efficiency is seen as a matter of public policy, if not specific government management and implementation.

A variety of public policy benefits and objectives were described above that ports are intended to help reach. Unfortunately, many of these benefits are very difficult to measure on their own; forecasting their future benefits and trying to aggregate such a heterogeneous collection of benefits is at best extremely difficult and expensive. Because the private markets for freight can be seen as relatively efficient, however, a port's ability to attract cargo may be taken as a rough proxy for the efficiency and effectiveness of its operations. Indeed, ports, public officials, and the trade literature almost all use the tons, total value of cargo, or number of containers as the measure of success for seaports. Therefore, it is often taken as implicit that in attracting cargo a port is

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[2] Winston and Bosworth, p. 267.

[3] A lengthy discussion of public expenditures on landside access to seaports may be found in Cowart (1994).

demonstrating increased efficiency and effectiveness, and thus helping attain public policy objectives that go beyond the financial benefits that may be more easily modeled. Thus, many governmental bodies view expenditures that increase port activity as potentially worthwhile long-term investments.

Nonetheless, from a still broader public policy perspective, there are issues of concern regarding the relationship between land-side access and seaports. There is often an opportunity cost of alternative utilization of either the investment capital or the scarce facilities dedicated to improving access. For example, there is often a significant opportunity cost to use of waterfront property for freight terminals. This applies to both shifting maritime terminal land to an on-dock rail facility, for example, or to a land-use unrelated to container throughput. Seaport access may be non-optimal to some jurisdictions, being tantamount to letting a port tail wag the dog of domestic containerization. The latter is much more important in the majority of regions. For example, if domestic cargoes must be handled at on-dock facilities, there are likely to be increased travel distances and greatly increased congestion near the port; if multiple local rail terminals are used, the result is likely increased operating and switching costs.

Finally, some articles in maritime trade journals express concern about the permanence of cargo that is attracted to a port by new investments. Such cargo is characterized as merely shifting from a nearby port in a zero-sum game, and a competitive response might result in cargo shifting back towards the original port. However, not all new cargo is merely shifting; investments that decrease transport costs do result in absolute gains in trade. Furthermore, most of the economic benefits of the gain in port efficiency usually come from the improvement in handling existing quantities of commodity flows, rather than from the new cargo attracted to the port. Thus, while cargo volumes may be a proxy for transport efficiency, many of the associated benefits can be achieved even without actual increases in cargo handled.

Chapter conclusion

Ports may thus be seen as important tools in achieving public policy goals, especially of an economic nature. Landside access is a very important factor in the efficiency of a port and its ability to attract cargo, but these investments are costly and their benefits hard to predict. Because port activity is a suitable proxy for success in reaching certain public policy objectives, there is appropriately some concern with the amount of cargo handled at a given port. However, over-investment is also a real concern, as there are often difficult to measure indirect costs , and the desired benefits in trade efficiency may be achieved even without an increase in cargo handled.

CHAPTER II. PRESENTATION OF PROBLEM

This chapter gives a brief description of some of the existing methodologies that are used to estimate the change in container activity at seaports from improvements in landside access. The motivation for a statistical methodology and the broad, generalizable models that it can produce is presented next. Theoretical explanations of the relationship between land-side access and seaport container activity are given. Finally, some specific predictions of the likely degree of influence of various factors is provided.

II.A. MOTIVATION

Traditional methodologies are very useful for presenting either broad qualitative overviews of many issues, or a detailed microeconomic analysis of very specific issues. However, consistent quantitative results generally are unavailable for any wide range of ports. Statistical techniques were selected to be pursued as a potentially fruitful and previously underdeveloped means of analyzing seaport container activity. The creation of broad rules of thumb may be useful to a variety of policy-makers interested in determining relative success or shortcomings in cargo activity at a broad range of ports, or long-term benchmarks for even a single port. In addition, they provide a quicker, easy-to-use, and inexpensive tool for making preliminary evaluations of port performance or related conditions.

II.A.1. Traditional Methodologies

The anecdotal nature of existing material on port activity and landside access has left many significant tasks for research on the topic. Comprehensive or consistent data on the frequency, pursuit, and results of the various motivations and strategies for improving access are difficult to obtain and almost always subjective in nature. The relative effectiveness and importance of the different strategies has therefore been examined using microeconomic analysis techniques, or on a case study basis addressing only a few ports at a time. This analytic treatment is completely consistent with the fact that policy decisions regarding the question of investment in landside access are typically conducted with regard to only one or to a few ports at a time. This limited policy scope is due to the decentralization of ports in the United States and the lack of multiple major ports in most other nations. Whether the investment is to be conducted by a national government, a port authority, a private railroad, a state department of transportation, or an integrated maritime/domestic carrier, the focus is appropriately on whether or not there is a net benefit in improving access to a given port.

Microeconomic analyses of cost savings from access improvements are usually supplemented with demand models, market surveys, and economic and environmental impact studies in order to reach an investment decision. In many cases, especially where ports are not governmental or parastatal organizations with broader mandates, financial analyses are also utilized in a similar manner for decision-making. While these are certainly appropriate techniques for individual ports, results usually are not readily transferable to other ports and are not even very robust over time, due to changes in market conditions and other exogenous factors. Consequently, these (often expensive) studies must be conducted repeatedly and do not always provide sufficient basis for broader decision-making.

Furthermore, a thorough analysis is usually only conducted when there is an obvious need or political pressure for access improvements. Such studies, due to their expense, are usually pursued on behalf of a party that is interested in improving access or that has a financial interest in one particular form of improved access. Thus, for detailed studies only rarely is the broader public policy perspective taken. Additionally, because of pre-existing infrastructure, accidents of history, and topographical considerations, the full range of issues is rarely examined for any port. When examinations have been conducted of broader issues in landside access, they have typically been conducted as qualitative case studies, and have rarely extended over wide ranges of ports. Investigations of smaller numbers of ports are able to produce detailed analysis of many issues, but again often lack generalizability. The specific geographic and institutional characteristics of almost any port are sufficient to raise concerns about how broadly lessons from studying it can be applied. The only qualitative studies identified that investigated landside access at numerous ports required substantial time and effort, and only covered ports within a single nation (the U.S.A.; hence, a single institutional context). As is usual in broad organizational surveys, the reports' conclusions provide more of a basis for institutional reforms and problem identification than guidance for specific courses of action.

II.A.2. Use of Statistical Techniques

The plural of anecdote is data.[4]

The above methodologies are quite useful for their intended applications. They can be adapted to be very effective for both broad overviews of many issues or a detailed analysis of very specific issues. However, such methodologies are frequently ineffective for comparing ports of different sizes, in different regions, or otherwise in dissimilar circumstances. The traditional methodologies often cannot be applied as quickly or cheaply as desired for either individual ports or, especially, over numerous ports. As is implicit in the above quote, there are times when one desires to take anecdotes, no matter how accurate or detailed, and aggregate them into data from which more general applications can be developed. In effect, there are no known benchmarks for gauging typical port activity over a variety of conditions, and a generalizable estimation formula fills this gap left by previous methodologies. This thesis broadly addresses the relationship between inland access for container movements and seaport activity, in an effort to provide more generalizable results. Statistical analysis provides a tool that permits such results to be generated.

The most general aim of this thesis was therefore to determine if the relationship between seaport access and seaport container activity could be quantitatively measured using statistical techniques. This methodology was met with some initial skepticism because of doubts about the availability of appropriate data and the difficulty in operationalizing variables for the key concepts. These concerns are well-grounded in the extent to which the access/activity relationship is dominated by or correlated with other factors, especially including geography and economic activity. The initial intuition for approaching the problem was to examine the causes of changes in container throughput at a seaport, that is, to conduct a time-series analysis. The determination was made that a cross-sectional approach was required to resolve many of the most problematic issues of data collection. While not as direct a means of examining the impacts of changes or differences in access on seaport activity, this methodology proved to be an effective solution to the problems of statistically modeling the access/activity relationship.

In particular, multiple regression techniques were selected to be applied to a relatively few critical variables for quite dissimilar ports in order to produce specific quantitative results. Furthermore, this methodology also produces confidence intervals that provide a measurement of the degree of certainty with

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4 Attributed to George Stigler, as quoted in Berndt, front endpiece.

which the conclusions can be judged. This methodology therefore is appropriate for fulfilling the need for a broad, generalizable model.

Additionally, the data collection process itself provided lessons regarding the availability of consistent, reliable data (suitable for statistical analysis) on population, economic activity, trade, and, especially, highway and rail access to seaports. For example, organizations such as the World Bank, the American Association of Port Authorities, and the ports themselves all benefit from knowing the extent of available data. As such, in addition to the specific operationalization of modeling techniques, this paper provides one structure upon which future data collection efforts may be based.

II.A.3. Potential users of generalized models

Landside access and seaport container activity have many significant economic and public policy implications, a substantial number of which relate to matters of a broader, national (or even international) level. Among these are such issues as international trade patterns, economic development, infrastructure capacity constraints, and national defense. Because of this, relevant investors and/or decision-makers often include actors such as national governments, integrated intermodal transportation providers, multinational manufacturing corporations, or international organizations. Of course, individual port authorities also have an interest in benchmarking their performance and in any additional insight that can be provided regarding general factors influencing container activity. For all these actors, a generalizable model of the relationship between landside access and port activity may provide a helpful tool.

Most directly, establishment of a statistically quantifiable relationship between landside access and seaport container activity across a broad range of political and economic conditions therefore provides a useful and generalizable technique for decision makers responsible for potential investment in port facilities and landside access. Even just demonstrating that such a model can be operationalized may be of merit to some large organizations that may wish to expand the scope, detail, and accuracy of the models estimated here.

International development organizations (including the World Bank and regional development banks, UNCTAD and UNDP, and the European Union), have an interest in utilizing performance indicators and benchmarks to measure the absolute and relative success or failure of different elements of many countries' economies. By use of such measures, more efficient targeting of sectors can be achieved and scarce funds can be better allocated.

Some national governments may join in this interest for more generalizable benchmarks, because of the need to address longer term-goals related to issues such as infrastructure redundancy and capital scarcity. Generalizable benchmarks can provide quick indications on whether ports are performing at a high or low level, and thus whether investment or policy reforms are warranted, or utilizing scarce resources when more worthy objectives may be deserving attention.

Even individual port authorities may benefit from such a tool, as it may provide a general, objective benchmark at which they could target their container activity. For example, competition between Charleston, Savannah, and Jacksonville may result in each trying to have the highest market share of the three, since that is the only measure of success available. However, if an objective benchmark is available to demonstrate that they are already performing above expectations for their level of national market access, then state port expenditures might go to other programs or tax cuts, rather than being spent trying to outdo one another merely because that is the only standard to measure themselves against. Perhaps the most telling evidence of port interest in this methodology is the extremely high response rate to the survey[5] and check-off rate to receive a copy of the executive summary and results of this work.

A major benefit to all actors of using such a tool is its ease of use and extremely low relative costs. The different model estimations presented in the results section can be applied directly, albeit the results found here may not be applicable outside the Western hemisphere. Nonetheless, a very quick set of figures can be generated for any port for which the basic demographic and economic characteristics of hinterlands can be determined (this is available in most research libraries). This process could generate estimates for several ports per hour once the process has begun. With a bit more research and data, the models including landside access variables could also be utilized to benchmark port activity. Finally, to reestimate these models on a broader geographic basis, or at some future time with more recent data, would likely consume only a month or two of one individual's full-time effort (with perhaps two more month's wait time for data collection). While these efforts are not insignificant,

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[5] Some 38 out of 81 (47%) ports responded to a single unsolicited written survey addressed to the Port Director. Several more responses (at a similar response rate) were received to a follow-up fax targeted at the largest ports that did not initially respond. These numbers exclude surveys filled out by individuals previously known by the author, and ports on several small islands for which landside access is not a consideration and the author was able to personally compile the appropriate container and demographic data.

they are far less than would be required under alternative methodologies to achieve such broad coverage. Of course given that these techniques are not proprietary, costs are basically limited to staff time and postage and similar overhead.

II.B. THEORY

Given the use of a statistical methodology, it is necessary to develop a conceptual framework in order to determine what factors should be examined for inclusion in the model. This first requires an explanation of the issues to be covered in the study. After determining an appropriate scope for the model and formulation of the dependent variable, an enumeration of the potential independent variables should be conducted. Finally, it is then very helpful to make a series of *a priori* conjectures about the expected characteristics of each variable's parameter estimates.

II.B.1. Conceptual framework of the model

The conceptual framework utilized in this analysis is a cross-sectional analysis of container throughput at seaports as a function of the demographic and economic characteristics of its potential markets and its level of access to these markets. Since this study was limited to loaded containers, this represents the combined level of demand for containerized exports and imports transiting the given port. The relative level of access to overseas markets ("ocean-side" access) is frequently considered homogenous for all ports in a given study. Because of the extremely broad range of ports covered in this study, this factor was accounted for to some extent in the model specifications. Nonetheless, the primary concern of this framework is the access of a given seaport to near and distant inland markets.

In typical microeconomic models of port activity, the key concept is that ports are able to attract all cargo for which they can provide a lower total transport cost from origin to destination. Any measurable improvement in access thus attracts new cargo to the port (although there may be rapid competitive responses). Inland costs are often able to be determined with some precision. In general, costs for trucking services for container movements average around $1.00 per mile of carriage required.[6] However, container handling, near-port

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[6] Caplice found an aveiage rate per mile of $0.998 for trucking, with an adjusted r-squared of 0.82 and 41,723 observations, in a regression estimate of long-haul truck load bids. *Optimization of the Carrier Bidding and Assignment Process*, forthcoming dissertation, M.I.T. Center for Transportation Studies. (fn. [1], cont.)

congestion, and other access issues result in costs for drayage typically being much higher per mile for distances up to approximately 100 miles. Rail costs are not quite as straightforward, with an even greater the "fixed" cost component for total rail charges as well as a variable (per-mile) cost, both of which can vary greatly under different operating situations.[7] Because of the accuracy that can be obtained in calculating these costs, microeconomic models of port cargo are also able to reflect small changes in access quite well.

While theoretically an assumption of perfect information would be made and the total cost of each network path for each individual origin-destination pair would be calculated, this is both an unrealistic assumption regarding shippers' knowledge and an unfeasible task due to data constraints. Thus, trade routes, commodity groups, and inland markets are usually aggregated to a considerable extent. Inland transport costs (before and after any access improvement) often would be calculated for different commodity groups for each geographic market area. Average costs for ocean shipping and port charges may be calculated for each relevant port, and each port would be assumed to serve all shipments for which it can provide the lowest sum of ocean, port, and inland costs. More sophisticated models would also incorporate travel time and unreliability costs (using a total logistics cost methodology), might disaggregate ocean costs by trade route and port costs by commodity type, or might include other refinements.

These concepts of a economics-based cost analysis are also the underlying basis for this study, albeit on an even more aggregated level. For example, the differences in access to overseas markets are very basically represented by whether or not the port is in northern North America, whether it is on the Pacific Coast and whether it is coastal or further inland than its competitors. The use of these three binomial indicators thus limits ports to being in one of eight cohorts of ocean access, with all ports in each implicitly assumed to have equal ocean transport costs with roughly the same commodity mix of containerized cargo.

The inland markets are similarly aggregated in a manner that facilitates distinctions in the time and cost of inland transport. Each of these markets has been termed a hinterland area in this study. Distance from the seaport and size of the hinterland, which can be measured in a variety of ways, are two very important characteristics of a given hinterland area. The degree or quality of physical access to these areas is also of great interest to seaports. The

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7 For example, the distance from the port docks to the railyard affects the fixed cost portion of movements, and the availability of double-stack rail service significantly reduces line-haul or variable costs.

hinterland for each port is divided into four areas in this study, each described by population and economic activity, as well as by the port's degree of access to each (a full description of these variables is provided in section III.B.2.). Again, the microeconomic concept of markets is aggregated, with inland transport costs assumed to be homogenous within areas for a given port, and identical for different ports except to the extent captured in a few access quality indicators.

Thus, microeconomic concepts have in a way been transformed through aggregation and assumptions of equal transport costs into an econometric means of allocating demand from hinterland areas. In addition to allocating market shares to different ports, the size of the market to be allocated must also be determined. A variety of techniques have been used in other studies in order to estimate the size of demand. In addition to market surveys and general equilibrium analyses, many previous studies have utilized econometric techniques to estimate overall freight demand, based on factors such as economic activity, or even modal demand or mode shares, by also incorporating freight rate and service quality indicators. A variation on these econometric approaches was utilized here to estimate the size of demand concurrently with allocating it among ports.

The above concepts were thus able to be individually incorporated into an econometric model, or reflected with the use of interactive variables or similar techniques. In particular, the following general specification was developed for this thesis:

demand (container activity) = f(population$_h$, economic activity$_h$, local congestion$_h$, regional highway access$_h$, rail access$_h$, and ocean access),

where the subscript h indicates the different values of the variables for each of the four different hinterland areas. Some of the above variables may also be made of several components. For example, rail access was composed of drayage time, number of rail terminals, a rail access rating, and a double-stack access rating. A full enumeration of the many variables formulated is given in section III.B.2. and Appendix D.

Thus, the existing concepts behind traditional microeconomic cost comparison models, and econometric estimates of freight demand were combined in this study. By applying the principles of both these techniques, a variety of appropriate model specifications were able to be formulated based on the underlying theory, and tested using standard statistical methods .

II.B.2. Expected results of the model

Because of the large number of variables that were available for analysis, *a priori* predictions about the expected characteristics of the parameter estimates were made for the different variables. Specifically, consideration was given to the expected sign and size of the coefficients, the expected statistical significance of the parameter estimates, and any potential interaction with other variables or other problematic characteristics of the data. The expected results for each of the factors theorized to influence the model results are presented below, while the description of how each of the variables was determined are provided section III.B.2.

Population should affect port container activity positively (i.e., have a positive coefficient). This variable directly represents the size of the import and export markets in terms of the number of consumers and producers. Because GRP alone overestimates consumption and production, population helps better account for the actual flow of commodities, and thus containers. This variable is expected to have a larger coefficient and be more significant in hinterland areas closer to the port, especially the metropolitan and local areas, and of decreasing magnitude and statistical significance further from the port (the truck radius and rail areas), as the shippers in any given area are increasingly likely to find another, lower cost alternative port as the given port becomes more distant, and thus more expensive to reach.

GRP, or Gross Regional Product, should affect port container activity positively. This variable represents the size of the import and export markets by serving as a proxy measure of the production and consumption of the hinterland area. Differences in GRP alone overestimate interregional differences in consumption and production. This is due to the fact that purchasing power for basic commodities is greater in lower-income countries than GRP alone would indicate, and because income elasticities of demand for containerized commodities are less than one (individuals do not buy directly proportionally more volume of goods as their income increases). As with population, this variable is expected to have larger coefficients and be more significant in hinterland areas closer to the port, especially the metropolitan and local areas, and of decreasing magnitude and statistical significance further from the port (the truck radius and rail areas).

Congestion represents increased delays and costs for transport in the metropolitan area around the port. It should therefore have negative coefficients for high congestion levels (low ratings) and positive coefficients for low congestion levels (high ratings). The significance of this variable may be somewhat low, since the effects are also likely to harm competing ports ability to provide service in the metropolitan area around the port; thus congestion may only cause a change in the cost differential as one moves away from the metropolitan area. However, this factor may instead be captured in the **Highway Time** variable.

Highway Time is predicted to have a negative coefficient, since ports with higher highway times have worse access to the local and trucking radius hinterlands. However, the significance is likely to be low, as this variable should only have influence on ports with a high dependence on these two hinterland markets.

Truck Access Rating is predicted to have positive coefficients for good (low) access ratings and negative coefficients for poor ratings. An important microeconomic relationship should be expressed by better truck access representing lower inland transport costs to the truck region, therefore increasing container activity at the port. The use of interactive variables should increase the significance of the results, since that would help account for differences in the amount of demand for which the access is being provided.

Drayage Time is predicted to have a negative coefficient, since ports with higher drayage times have worse access to the rail hinterlands. However, the significance is likely to be low, as this variable should only have influence on ports with a high dependence on the rail hinterland markets. Additionally, the significance may be low if other rail variables are in the specification, because they may tend to mask this factor.

Rail Terminals is predicted to have a positive coefficient, since ports with a higher number of terminals nearby are more likely to have better access to the rail hinterlands. Additionally, multiple nearby terminals may represent increased price competition between railroads, and thus lower inland costs and higher container activity. The significance still may be only low to moderate, as this variable should only have influence on ports with a high dependence on the rail hinterland markets. Additionally, the significance may be low if other rail variables are in the specification, because they may tend to mask this factor.

Rail Access Rating is predicted to have positive coefficients for good (low) access ratings and negative coefficients for poor ratings. An important microeconomic relationship should be expressed by better rail access representing lower inland transport costs to the rail hinterland region, therefore increasing container activity at the port. The use of interactive variables should increase the significance of the results, since that would help account for differences in the amount of demand for which the access is being provided. Utilization in the same specification as other rail variables may decrease the significance of these parameter estimates somewhat.

Double-stack Access Rating is predicted to have positive coefficients for good (low) access ratings and negative coefficients for poor ratings. An important microeconomic relationship should be expressed by better double-stack access representing lower inland transport costs to the rail region, therefore increasing container activity at the port. The use of interactive variables should increase the significance of the results, since that would help account for differences in the amount of demand for which the access is being provided. Utilization in the same specification as other rail variables may decrease the significance of these parameter estimates somewhat. Because this variable represents an operational practice present at fewer ports, the significance may be somewhat less than that for the rail access rating.

Inland Port should have a negative coefficient and be significant. As a direct proxy for ocean access relative to nearby competing ports, it represents an increase in ocean transport costs. The few number of observations with this characteristic may limit its significance somewhat.

US/Canadian should have a positive coefficient and be significant. Because these countries are closest to the Hemisphere's major trans-oceanic trading partners (Europe and Japan/the Far East), this variable acts as a proxy for ocean access relative to other ports in the hemisphere. Additionally, this variable may capture the impacts of North American domestic intermodalism and higher levels of containerization, reinforcing the expectations regarding the sign and significance of the parameter estimate.

West Coast should have a positive coefficient. Because these ports are closer to the Hemisphere's largest trans-oceanic trading partners (Japan/the Far East), this variable acts as a proxy for ocean access relative to other ports in the hemisphere. This variable is expected to be marginally significant, and less so when in the same specification as **USCAN**.

Island Ports did not have an expected direction for the coefficient. The author was unable to, *a priori*, rationally conjecture whether island ports benefited from the lack of competition and the increased need to transport all commodities by ship, or if there activity would be lessened by the lack of any substantial market very far away. Because of this uncertainty, no expectation could be reached regarding this variables significance either.

Chapter conclusion

Traditional methodologies are useful for individual port analyses, but are not always able to provide results of a broader perspective. This thesis focuses on trying to create some generalizable estimates of seaport activity as a function of access and other factors. Creation of some handy rules of thumb is to the benefit of several types of governmental and non-governmental organizations. By collecting and analyzing data on ports' hinterland markets and landside access, a statistical model was developed providing generalizable conclusions regarding appropriate contexts for improvements in landside access. A conceptual framework based on established methodologies was presented. *A priori* expectations of variables could then be made, with a number of them appearing promising for use in regression models.

CHAPTER III. METHODOLOGY

This chapter describes the characteristics and implications of the use of a statistical methodology, and describes the specific steps taken to operationalize a statistical model of seaport container activity. The implications of statistical methodologies in general and of regression techniques in particular are provided. Next, the determination of the range of the topic to be modeled and the variables chosen for data collection are stated. Specific tasks undertaken in the data collection process are provided, along with the descriptions of the data sources and their expected reliability. The data set collected in this work was sub-divided for some model estimations in order to utilize a wider range of specifications. A full set of specifications, including the use of explicit landside access variables, was explored for the 49 ports for which complete information was obtained. Many of these specifications were also utilized for the larger set of 99 ports for which only seaport activity and demographic and economic characteristics of hinterlands could be obtained. Additionally, estimations were made on various cohorts of the large data set for statistical diagnostic purposes. Finally, the explicit formulation of the variables and the standards utilized in developing the model specifications are delineated.

III.A. IMPLICATIONS OF USING STATISTICAL TECHNIQUES

> *Econometrics recognizes that social behavior is exceedingly complex and that a limited number of variables related together in fairly simple and elegant equations cannot explain the whole of such behavior*[8] ; nevertheless, econometricians devote their lives to such exercises.

Statistical methodologies provide a means for organizing and analyzing data in a consistent, objective manner. In effect, statistics allow analysts to draw conclusions about the characteristics and behavior of some population or series of phenomena from a smaller sample. As such these methodologies can serve as extremely effective tools for presenting summaries that aid decision-makers in making investment or policy judgments. In areas such as landside access, where existing guidelines and rules of thumb are largely based on incomplete or imperfect information, statistical analysis can help provide a consistent basis for decision-making.

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[8] Lawrence R. Klein, *A Textbook for Econometrics*, Evanston, Ill.: Peterson and Co., 1953, pp. 1-2. Quoted in Berndt, front endpiece.

Of course, care must be taken in utilizing the results of statistics as the sole basis for inductive reasoning regarding investment or policy decisions. The limits to the reliability of any data obtained by survey, changes in transportation technology or operational procedures, and the presence or emergence of factors not accounted for in the statistical analysis all limit the extent to which results can be applied indiscriminately. Rather than serving as an exclusive tool for decision-making regarding landside access, statistical models are better utilized as guides to focus additional studies of a more detailed nature into the most critical areas.

It has been stated that econometric "forecasting is like trying to drive a car blindfolded and following directions given by a person who is looking out the back window."[9] In other words, the general advice of which direction to go can be trusted on average, but any variation ahead that is substantially different from what has been evidenced previously is likely to produce unexpected results. Nonetheless, statistical techniques additionally provide knowledge regarding the degree of confidence with which estimates can be treated, so that the metaphoric driver has at least some basis for judging how fast the goal can be approached and how much additional guidance is likely to be necessary. In summary, this initial operationalization of a statistical model provides some decision-makers with a new tool for determining which ports and landside access issues to consider for further examination and potential investment.

III.B. DETERMINATION OF SCOPE

This section describes the rationale behind focusing primarily on containerized cargoes. The study's geographic limitation to ports in the Western Hemisphere is explained as an effort to facilitate data collection while maintaining an adequate sample. Next, a justification is presented for concentrating on physical infrastructure improvements, namely rail and highway access, although broader alternatives for access enhancement are also briefly discussed. Lastly, the explicit variables selected for consideration are described.

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9 Anonymous, quoted in Berndt, p. 306.

III.B.1. Factors Considered

Because of the broad range of issues related to access to seaports, special care must be taken in providing focus to any discussion of the topic. Furthermore, cargo, seaports, access, and the parties interested in these topics are each represented by a diversity of cases, and some effort should be made to narrow the examples under consideration. Correspondingly, this paper primarily concentrates on public interest and involvement in how access to container ports influences container activity. However, at times some attention outside this area both is necessary, due to data limitations, and advantageous, in order to broaden applicability.

III.B.1.a. Cargo type

Maritime cargoes are commonly separated into the categories of dry bulk, liquid bulk, ro-ro, containerized, heavy-lift and specialized cargoes. Because ro-ro ("roll-on, roll-off" commodities, mostly automobiles), heavy-lift (generally construction or heavy manufacturing equipment), and specialized (molten sulfur, super-cooled cargoes such as LNG, etc.) cargoes are relatively small in quantity, require special handling and port facilities, and often serve limited markets, they make poor choices as the basis for developing a generalizable model. While liquid bulk cargo (primarily petroleum) is plentiful and relatively ubiquitously present as either an import or export, its maritime terminals are often private facilities for which data is inaccessible. Furthermore, liquid bulk's inland movements are primarily by barge and pipeline, which function as a separate infrastructure system from that utilized for other cargoes. Containerized cargo represents a strong majority of international trade by value, and has a much higher average value per ton than either liquid or dry bulk cargoes (oil, wheat, coal, and iron ore) or "break bulk" cargo (such as coffee, cocoa, rice, etc.) Trade and port choice in heavy, lower value items, such as bulk and break bulk cargoes, are also more dependent on natural resource locations, rather than landside access.

The container revolution has resulted in the near-total dominance of containerization in the international maritime movement of non-bulk goods. By 1990, at least 80% of the value and volume of liner imports to the United States moved by container.[10] Because most non-containerized cargo uses rail, barge, or pipeline for the inland portion of its transport to or from the seaport, the vast majority of truck trips to port facilities involve container movements. On the rail side, because containers average much higher value per unit

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10 Transportation Research Board (1992), p. 14.

volume than bulk shipments, the total logistics costs[11] for containers are much more sensitive to the variations in travel time and reliability, factors which are strongly affected by relative ease of access. Therefore, for most current interest in issues such as transportation efficiency and rail and highway access to seaports, containers are the appropriate cargo on which to focus. Additionally, because of the great deal of recent attention to the role of containers in international trade, and the relative homogeneity of access issues that they face, containers may not only be the most relevant, but may be one of the easier areas to examine. Fairly comprehensive published data is available on container throughput at many of the world's seaports, and the finite number of ports handling containers made collection of similar summary data a tractable task.

In determining the specific measure of containers that is most appropriate to represent port activity, several perspectives can be taken. First, a standard measure should be used to insure consistency between ports' data. The TEU, or twenty-foot equivalent unit is the maritime and intermodal industry's standard, and represents a consistent measure of cargo volume. One TEU is equal to the volume of a single 8′ x 8′ x 20′ container, and other containers are simply prorated to this measure. One drawback of simply measuring TEUs of port activity is that certain ports have high proportions of empty container traffic, due to discrepancies between imports and exports. Empty container traffic is therefore mostly an artifact of trade imbalance, rather than aggreagate economic activity or landside access. Thus, TEUs of loaded containers provides a better measure of the relationship between landside access and seaport activity.

A similar problem exists with transshipments, the process by which one ship leaves a container at the port for loading on to another ship. Transshipment is primarily an issue of inter-terminal access and load-centering, and is based on the existence of feeder services and hub-and-spoke networks for ship operating economies. Because their quantity is largely unrelated to land access to hinterlands, transshipped containers should not be considered in this evaluation. While the extent of this issue is potentially large, with the two largest containerports in the world, Hong Kong and Singapore, dealing extensively with transshipment, the limited data available indicates that transshipment is not a significant factor at ports in the Western Hemisphere, except at the ports immediately adjoining the Panama Canal. Nonetheless,

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11 Discussions of the logistics costs concepts can be found in Graham and Hughes (1983), Marcus (1993), Muller (1993), with comprehensive treatment in Lambert and Stock (1995).

consistent data was not available excluding transshipped containers, and so all loaded containers fell within the scope of this study.

In summary, while seaports deal with a variety of cargoes, these are not as appropriate as containers for an understanding of landside access, international trade, and economic activity. Loaded, non-transshipped containers would be the best measure of international trade activity which is most strongly influenced by landside access improvements, but transshipment appears to be relatively minor in the Americas. Both port activity (by value) and international trade are best represented by the level of container movements, since this one factor represents a very wide variety of goods from diverse economies and of a wide range of values. The relative homogeneity and availability of data on containers make them especially suitable for statistical analysis.

III.B.1.b. Geographic focus

The Western Hemisphere was selected as the area of study for this analysis. The ports studied were limited to the Western Hemisphere to make data collection more manageable, while still providing a sufficient sample of ports in relatively diverse contexts. Maps displaying the relevant areas and port locations are provided in Appendix A. With 122 of the approximately 400 significant containerports in the world and 20% of the world's volume of container traffic, the hemisphere provides a suitable sample size. Additionally, the number of nations and different institutional contexts, variety of economies, and spectrum of geographic characteristics indicates that the Americas possess sufficient diversity to be representative of containerports throughout the world. The sample size was also limited in this manner in order to facilitate the collection of data; the author's location and familiarity with the appropriate languages further influenced the choice.

One significant issue encountered with this geographic selection is that the preponderance of data available for this thesis was from the United States. This is hardly surprising as the United States represents approximately one-third of the containerports and three-quarters of the container flow in the Western Hemisphere, and approximately one-tenth of the world's containerports and one-sixth of all container traffic.[12] Regardless of how one geographically divides the world's ports, however, one would face a similar issue of a concentration of activity. The top 20 containerports in the world receive over half of the world's container traffic, and the top 6 nations in container activity represent a similar majority. Since this pattern of container activity exists throughout the world, its presence in the selected area was viewed as a representative characteristic of the world port population to be modeled, rather than an aberration of the data sample.

As another issue of possible concern, the United States also differs from most other nations in the extent and distance of inland container movements, and hence the nature of access issues its faces is also different. However, to a considerable extent, Canada experiences patterns of container movements similar to the U.S., and, especially under NAFTA, it can largely be considered part of the same intermodal transportation network as the United States. As mentioned above, Hong Kong and Singapore serve extensively as transshipment points, with access being primarily an inter-terminal issue. None of the other top thirteen nations for container traffic possess nearly the extent of economic or geographic hinterland that U.S. containerports possess, although Europe is moving towards a similar pattern of greater inland container movements. The degree to which this issue affected the results is minimal, however. An indicator variable was utilized for U.S. and Canadian ports, and when statistically significant the variable was included in the models. Furthermore, several specifications were estimated that accounted for the possibility of structural differences in the relationship between ports and access in the U.S.A. and Canada compared with the rest of the hemisphere.

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12 *Containerisation International Yearbook -- 1994*, p. 6.

This modeling issue of national differentiation applies in the converse as well. Few developing nations currently experience extensive use of containers; China leads the list of low-income countries at 11th in container traffic, while Brazil is first among low-income nations in the Western Hemisphere at 27th.[13] One reason for this is a problem unlikely to be remedied soon: ". . . if inland transport systems in less-developed countries are unable adequately to handle container traffic, this factor alone can seriously affect the efficient operation of the system."[14] While these issues call into question the pure applicability of data, in either direction, between developed and less-developed nations, the use of the economic activity variables provides an excellent tool for modeling these issues. The world, of course, is made up of a spectrum of economies, no matter how bipolar it may sometimes seem, and the use of continuous variables such as gross domestic product appears to be a superior way to statistically describe this characteristic, rather than exclusively with discrete indicator variables of national development.

III.B.1.c. Appropriate elements and measures of access

A variety of other, more general issues also have been considered issues of access to seaports. While not technically issues of landside access, nor easily amenable to statistical modeling, they bear a brief mention. Legal, organizational, regulatory, and institutional barriers to access can be substantial: customs, agriculture inspection, and administrative and documentation requirements are some of the more obvious examples of factors that could be considered access hurdles. Although these are issues where policy-making entities certainly can have a significant impact on access, they do not really fit within the concept of access enhancement through investment or similar decision-making processes. To maintain the focus of the analysis, this discussion of landside access has been largely limited to issues of an explicitly transportation nature.

The initial simplifying assumption of using containers as the measure of trade allows consideration of landside transportation modes to be practically reduced to rail and highway. While barges are used in a limited number of locations (for example, in the Western Hemisphere, from Portland, Oregon and elsewhere on the Columbia-Snake River system), a statistically significant number of barge facilities could not be located. Therefore, access to seaports for containers is best measured by the level of service available on both rail and

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13 *Containerisation International Yearbook -- 1995*, p. 6.

14 Hoyle, p. 192.

highway, and the characteristics of the hinterlands that they serve. It was expected that one of the most significant challenges of this study would be to discover if appropriate variables could be developed to accurately reflect the quantity and quality of landside access to seaports. A variety of combinations of traditional transportation service measures and proxy variables, such as measures of travel time, congestion, and the presence of multiple access options, were thus investigated.

In the end, the only explicit transportation performance measures found available in a consistent form, and suitable for use in statistical modeling, were truck travel time to the regional highway network, drayage time to the most frequently used rail terminal, and the number of frequently used rail terminals. Subjective, but well-defined, ratings of congestion, regional trucking access, regional rail access, and double-stack rail availability were also gathered; the specific rating systems are presented in the questionnaires referenced in Appendix B.

There is a consensus as to the importance of the concept of access, or perhaps more properly accessibility, but there is little agreement as to its definition. However, attempts at definitions of accessibility almost always include both the transportation system and locational considerations. The importance of the latter element can be illustrated by two hypothetical ports with exactly equivalent transportation systems, but with one having a much larger nearby population, and hence much greater market access. The breadth of landside access issues can be difficult to demarcate when the spatial dimension is explicitly added to the already diverse vectors of measuring a transport system. Because of the problematic nature of this locational issue, representations of accessibility were forced to take somewhat simplified and abstract forms. Other accessibility measures were thus represented as the populations and gross regional products of the port's metropolitan area, the local region to which it possesses a natural geographic advantage, the region within the empirically determined trucking radius of 400 miles, and the region accessible by rail from the port. Such population and economic activity measures were then interacted with the indicator variables of access ratings to generate accessibility measures. For a full description of demographic variable operationalization and the development of interaction variables, see section III.D., below.

Adjoining transportation bottlenecks must be considered, even when limiting discussion to landside transportation access, due to the interdependence of transportation networks,. This is because they are an element of access and relate directly with explicit elements of landside transportation access. For example, dredging and maritime terminal issues are interrelated with the motivation and success of landside access, since they may act as a constraint or an incentive for investment. Ironically, dredging and double-stack can be viewed as the converse of one another. For example, channel dredging is analogous to "waterborne double-stack," and double-stack to "landside dredging." Their interdependence, and the need for balance between them, become obvious as either becomes a constraint. An indicator variable was thus provided for ports which faced some form of substantial maritime access constraint.

Similar arguments follow for maritime terminal issues. If a port has insufficient handling capacity or storage space, corresponding problems can be seen as, for example, queues of trucks wait to load and unload. Shortcomings in management, labor, or information systems are all areas where inefficiencies can also result in these container throughput problems; containers can sit for weeks due to organizational shortcomings. In some cases, these issues relate directly to landside access. Improved gate systems or maritime terminal throughput can eliminate truck queues on nearby streets; on the other hand, seaport-bound trucks and trains block one another wherever there are grade crossings. The characteristics of terminal throughput directly relate to the capacities necessary on the landside. Data collection efforts on this issue fell short, as many ports did not have data available regarding their leased container terminals, and apparently unclear wording on the relevant questions resulted in inconsistent answers on a number of questionnaires on which terminal data were provided. While the element of terminals was not explicitly present in the statistical analysis, it nonetheless was likely implicitly considered due to the strong relationship terminal issues have on drayage times, highway access times, and the subjective ratings of port access.

In summary, a series of arguments have been made above on why and how the focus of the analysis is appropriately on the explicit transportation elements of landside access. Furthermore, because decision-making regarding enhancing seaport access has been shown to be largely related to containers and landside transportation, highways and rail are the primary focus. While the focus of the analysis is clearly and explicitly land transportation-based, a variety of related issues have been at least partially incorporated into the measures of access. Furthermore, the effort to maintain a narrow focus should not be viewed as a limitation, but as an opportunity. Not only does this limiting of the scope facilitate statistical analysis and permit thorough consideration of what many view as the most critical elements of seaport access, but the above discussion delineates numerous directions in which the applicability of this work can be expanded incrementally.

III.B.2. Variables selected

Based on the issues raised in the previous section and the results of the data collection process, a large number of variables were operationalized for use in formulating alternative specifications of the model. The full set of variables is described here, broken down into groups by subject areas.

<u>Dependent variable:</u>

TEU Number of loaded, twenty-foot equivalent units of containers handled by the seaport in 1993.

<u>Independent (explanatory) variables:</u>

Demographic and Economic Variables:

METPOP Population within the port's Consolidated Metropolitan Statistical Area ("CMSA"), or the equivalent; generally the area of continuous urban development at populations densities of at least 5,000 persons per square mile.

METGRP The gross regional product ("GRP") within the port's CMSA, or the equivalent; as calculated for METPOP. For the U.S., per capita incomes were available on a per city basis, and were multiplied by the METPOP to determine GRP. For other nations, national per capita gross domestic product ("GDP") were multiplied by METPOP.[15] All of the GRP variables are expressed in millions of dollars.

LOCPOP Population within an area, not larger than a 200-mile land radius, to which the port has a natural geographic access advantage over other ports (see Figure III-1, below). In cases where two or more ports are within the same CMSA, then a single LOCPOP was calculated for the ports, and this figure was divided by the number of ports in the CMSA. Populations for LOCPOP (and TRKPOP) were compiled using a compass and series of atlases,

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[15] U.S. figures used for urban per capita incomes averaged very near to national per capita GDP, and were deemed a better indicator for METGRP because of the significant differences found in per capita income between cities. Unfortunately, per capita GDP was not available below the national level for any of the studied nations.

along with population and population density data for cities, counties, states, provinces, and other administrative districts.

LOCGRP The GRP within an area, not larger than a 200-mile land radius, to which the port has a natural geographic access advantage over other ports; calculated by multiplying per capita GDP or income by LOCPOP. All of the GRP variables are expressed in millions of dollars.

TRKPOP Population, excluding the port's METPOP, within a 400-mile land radius travel distance of the seaport. Populations compiled as with LOCPOP.

TRKGRP The GRP, excluding the port's METGRP, within a 400-mile land radius travel distance of the seaport; calculated by multiplying per capita GDP or income by TRKPOP. All of the GRP variables are expressed in millions of dollars.

RAILPOP Population practically served by rail from the port. By definition, this population must be within coverage of the national or international rail network utilized by the port, and furthermore, areas to which rail service would not be economically feasible must be excluded. Ports were assumed not to serve areas within their truck radius, nor areas within the truck radius of other ports on the same coast, unless contradictory information was available for the given port. Ports with rail access across international borders (e.g., many ports in the U.S., Canada, Mexico, Brasil, Uruguay, Paraguay, and Argentina) were considered to serve such areas fully, to the extent consistent with the above guidelines and other available information regarding trade barriers or border crossing constraints. Nonetheless, ports were considered to have access to all populations for which service is currently feasible, even if such service does not currently exist to the given area. For example, ports in the northeastern U.S. with rail access were considered to have rail access to those areas of western and midwestern Canada and the U.S., as well as northwesternmost Mexico, at least 400 miles from East Coast and Gulf Coast ports. To the extent possible, judgments of rail coverage were based on the results of returned questionnaires, the 1991 AAPA landside access surveys and associated MARAD reports, and reviews of the trade literature. If the port did not utilize rail transport, then this variable was assigned a value of 0.

RAILGRP The GRP of the area practically served by rail from the port. Calculated by multiplying national per capita GDP by RAILPOP, aggregating populations by nationality for ports with international rail access. All of the GRP variables are expressed in millions of dollars.

Further Insights Regarding the Hinterland Variables

The size of the nearby population and extent of regional manufacturing and consumer activity naturally impacts the quantity of containers that flow through a given port. Appropriate economic and demographic variables for ports' markets were developed in order to measure their impact on container throughput. As described above, other accessibility measures were thus represented as the populations and gross regional products of the port's hinterlands.

The metropolitan area was selected as representative of the immediate hinterland market for the port. Cargoes are likely to utilize the port both because of actual transport cost advantages and the tendency of shippers to perceive a port as the natural gateway to its surrounding urban area.

The local region was developed to represent a nearby hinterland for which some natural geographic advantage, such as travel distance, is held. Examples would include eastern New England for Boston, northern Brasil for Belem, and Alabama for Mobile, while Delaware and southeastern Pennsylvania would be split between Philadelphia, Chester, and Wilmington, Del. This variable delineates the effects of competition from nearby ports by giving smaller LOCPOP and LOCGRP values to ports with nearby competitors. Thus, Mobile's LOCPOP is much greater than its METPOP, while Philadelphia's LOCPOP is actually smaller than its METPOP since it is sandwiched between New York and Baltimore and must share its small local region with two other ports. Only in cases of multiple ports within the same CMSA did local regions overlap or coincide, and in these cases the local region population was split evenly between the ports and had no overlap with the local regions of other ports or CMSAs. Although responsive data on the local and regional market shares for ports was only available in about two-thirds of the questionnaire responses, this was sufficient to confirm the general validity of this means of operationalizing this concept.

The trucking radius was developed to represent that population which is readily served by truck rather than rail from the same (or possibly another) port. While 500 miles (or even greater) is a standard rule-of-thumb for that distance at which trucking is unquestionably competitive over rail, the questionnaire results indicated a radius of around 400 miles. A straight line

Figure III-1: Operationalization of Demographic Variables

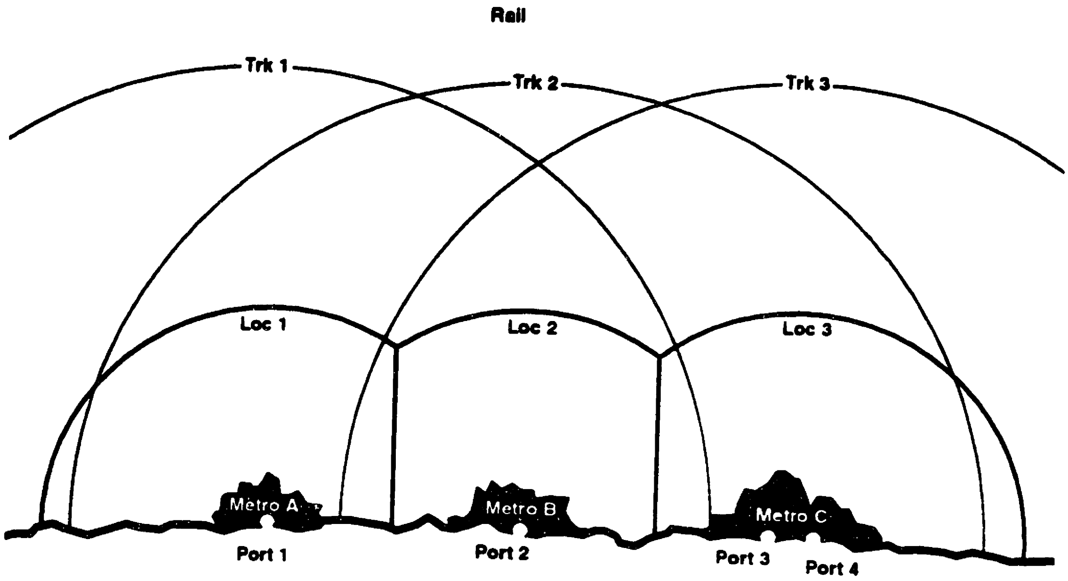

Figure III-1 illustrates the typology developed for operationalizing hinterland characteristic variables such as population and economic activity. Four ports are shown located along a coast Ports 1 and 2 are associated with Metropolitan areas A and B, respectively, while Ports 3 and 4 are both associated with Metropolitan Area C. Port 1 has Local region 1 as its area of geographic dominance. Sandwiched in the middle, Port 2's Local region is smaller, and likely less populous. Ports 3 and 4 share Local region 3, so their data for this hinterland region each reflects only half of the population and economic activity in that area. Each Port has all of the population and activity occurring within its respective trucking radius entered as data for those variables. The population and activity served by rail includes only that area beyond the truck radius of all ports along this coast

400 mile radius (as the crow flies) was therefore the usual standard utilized, which roughly approximates a 500 mile highway distance. In cases such as island ports, Chilean and Peruvian ports greatly restricted by the Andes, ports on peninsulas, etc., the road network was more closely examined to determine the approximate population coverage by trucks. Additionally, where specific evidence could be found in trade journals or port authority literature regarding the size of the trucking market for a given port, this information was utilized.

The rail region was considered the entire relevant freight rail network if rail was available and utilized for container movements to and from the port. Data on the availability of rail at ports was obtained both from questionnaire responses and from terminal descriptions in the most recent editions of *Containerisation International Yearbook*. In most cases examination of rail networks on a variety of atlases led to the entire, or a strong majority of the national population and GDP, and even neighboring nations, being determined to be accessible by rail. However, some countries (e.g. Venezuela and Peru) had very limited rail networks accessible from their ports.

Transport Availability and Quality Variables:

CON2, CON3, CON4, CON5	Ratings were given by ports and carriers on a scale of 1 (extreme) to 5 (very little) for the level of congestion typically encountered in the port's metropolitan area. No ratings of "1" were received. The variables were then formulated as indicator (or "dummy") variables.
HWYTIME	The average time from terminal gates to the closest major, intercity highway, expressed in minutes.
TRKRAD	The distance within which most containers transported to or from the port would be moved by truck. Beyond this distance, rail would typically be used as the alternative. Expressed in miles.
TRK1, TRK2, TRK345,	Ratings were given by ports and carriers on a scale of 1 (excellent) to 5 (poor) for the overall level of regional truck access that the port provides to markets. Only one rating of 4 (below average), and no 5's were received, therefore a single indicator variable was used to group the 4 with the 3's.
DRAY	Average drayage time from the terminal gate to the most commonly used rail terminal. Expressed in minutes.
TERMS	The number of frequently used container-handling rail terminals, expressed as a cardinal number.
RAIL1, RAIL2, RAIL3, RAIL4, RAIL5	Ratings were given by ports and carriers on a scale of 1 (excellent) to 5 (poor) for the overall level of regional rail access that the port provides to markets at least 500 miles distant. The variables were formulated as indicator (or "dummy") variables.

DS1, DS2, DS3, DS4, DS5	Ratings were given by ports and carriers on a scale of 1 (full high-cube availability) to 5 (unavailable) for the overall level of double-stack rail service provided by or near the port. The variables were formulated as indicator (or "dummy") variables.

These variables were sometimes used directly in model specifications in order to explicitly determine the impact of their role in landside access in port activity. For the indicator variables, however, it was frequently found useful to develop interactive variables that combined elements of transportation access with the size of the hinterland to which access was being provided. These interactive variables are described below.

Geographic description variables:

ISLE This indicator variable was given a value of 1 if the port was located on an island, and otherwise had a value of 0. This variable was used to capture the effects of topographic limitations more stringent than the other measures of market size.

INLAND This indicator variable was given a value of 1 if the port was located inland at least 50 miles up channel from the coast, and otherwise had a value of 0. This variable was used to capture the port selection behavior of ocean carriers, who often try to avoid the additional travel time (approximately 12 hours, round trip, for 60 miles) that long, slow trips up channels require. However, the Pacific Northwest ports (Vancouver, Seattle, Tacoma, Portland) were all given a value of 0, since trans-Pacific carriers, for practical purposes, must call at at least one port in the region, there are no significant coastal alternatives, and their locations therefore do not cause the diversion of ship calls.

USCAN This indicator variable was given a value of 1 if the port was located in the United States or Canada, and otherwise had a value of 0. This variable was used to capture the effects of the beneficial location on world trade routes, higher level of containerization, impacts of domestic intermodalism, and beneficial institutional and regulatory environment of the United States and Canada.

WEST This indicator variable, also delineated **PACIFIC** in Tables IV-1 through IV-8, was given a value of 1 if the port was located on the Pacific coast and serves as a gateway for hinterland regions that are also served by non-Pacific ports; otherwise it had a value of 0.

This variable was used to capture the beneficial effects of a location on the busy ocean trade routes from the far east. This variable also helps account for the relative scarcity of natural harbors on North America's Pacific compared to Atlantic coast; with fewer harbors, each is likely to attract more traffic on average. Ports such as Vancouver, Los Angeles, Mazatlan, Buenaventura (Colombia), Callao (Peru) and the Chilean ports all were assigned this indicator. Anchorage and the various Hawaiian ports did not receive this designation since, as the sole port for their hinterlands, they were not attracting any additional cargo by virtue of their location on the Pacific rather than the Atlantic.

Data transformation and interactive variables:
As has been previously described, numerous data transformations were performed in order to allow a broader range of model specifications. Several sets of transformations were performed in order to determine whether common non-linearities might provide better models of behavior than pure linear specifications. Numerous variable interactions were also conducted, in which population and economic activity measures for the appropriate hinterland areas were interacted with the indicator variables of transport quality and availability ratings to generate accessibility measures. A description of some of the more illustrative transformations and interactions is presented here. A full listing of the (most relevant) interactive variables, including their operationalization, is given in Appendix D.

Illustrative Examples of Interactive Variables:

METPOPSQ = METPOP * METPOP
LOGTEU = LOG(TEU)
CON2X = CON2 * METPOP
TRK345X = TRK345 * TRKGRP
TRKB12X = TRKB1X + TRKB2X
DS123 = DS1 + DS2 + DS3
DS4X = DS4 * RAILGRP

Miscellaneous variables:

ONE This variable was given a value of 1 for all ports and utilized as the constant term in model specifications.

RANK This variable was given a value equal to the rank of the port in container activity, as measured by 1993 loaded TEUs. The 99 ports were given an ordinal ranking out of the 122 ports in the Western Hemisphere for which container volume could be ascertained. The variable was used for data identification and to examine correlations, and was not utilized in any regression models.

OBSNUM This variable describes the order in which the data for each port was read into the statistical software. The variable was used solely for data identification when examining residuals and predicted values, and was not utilized in any regression models.

These variables were read into the regression software for use as a constant term in model specifications and for data identification purposes when examining residuals, etc.

In summary, the size of different hinterland areas were formulated with both population and GRP, and were developed to reflect the critical issue of the size of the markets to which access is being provided. Transport availability and quality was operationalized through a series of variables obtained from ports and carriers. Highway access was measured by the travel time to the regional highway network, local congestion, and a subjective regional rating. Rail access was measured by the number of rail terminals in the port terminal area, drayage time to railyards, the presence of double-stack operations, and a subjective overall rating. Several geographic indicators were found useful in describing the special situations some ports face. Data transformations were important in creating interactive variables that perhaps provide the best single way to measure accessibility. This comprehensive set of variables together yielded a wealth of specification permutations, thus allowing significant flexibility in developing the statistical models.

III.C. DATA COLLECTION PROCESS

The development of a dataset of port activity, demographic and economic characteristics of hinterlands, transportation quality and availability, and related accessibility measurements suitable for statistical analysis was one of the primary challenges of this research. A questionnaire was developed to serve as the primary source of information regarding landside access variables. This questionnaire would also serve to help develop and confirm port activity and hinterland characteristic research. The latter data collection task was a largely straightforward but laborious effort of reviewing maritime data sources, atlases, and demographic research sources and compiling relevant data for each seaport. In all, complete data was compiled for 49 ports, and container activity and demographic and economic characteristics of hinterlands data was available for 99 ports.

III.C.1. Development and Dissemination of Questionnaire

The initial step in developing the questionnaire to be utilized was the determination of which landside access variables would be most critical in formulating a statistical model. While there are numerous transportation performance measures of potential interest on this topic, it was determined that a short questionnaire would be necessary to obtain an adequate response rate to the effort. Finally, performance measures selected were developed to be simple, clear, and obtainable, so that consistent results could be received with a high response rate for all questions. Initial drafts of the questionnaire were reviewed by MIT faculty, port authority personnel, and an experienced federal maritime professional, with the final draft reflecting a variety of improvements; nonetheless, the author did not catch all ambiguities, resulting in poor response reliability to a few questions.

Ports and carriers were deemed to be the best source of information for issues of container transport modes and distances, port competition and market share, truck access performance measures, and critical terminal access characteristics. Additionally, it was thought that ports would be able to readily provide the most accurate and up to date figures for container traffic. For container transport, the most straightforward issues were the effective distance where rail starts becoming competitive with trucking, and the mode shares for trucking, rail, intermodal moves, and other modes. For port competition, the critical issues to address were each port's metropolitan and local region market share, and a breakdown of container traffic by transport distance. Urban congestion levels, major highway access, and regional truck access were selected as the most relevant truck access questions easily answered by ports. Rail access performance measures readily answerable included drayage time, number of rail terminals, double-stack rail availability, and overall rail access. Finally, terminal operations were measured utilizing average handling costs and terminal dwell times. Translations into Spanish and Portuguese were primarily conducted by native speakers with professional maritime experience. The full questionnaire appears in Appendix B.

The survey was distributed to 81 ports in North, Central and South America in July 1995, and several large ocean carriers were also contacted and agreed to complete questionnaires for several of their ports of call. Islands with only a single port were largely excluded from the questionnaire distribution, since their geographic circumstances render many of the questions meaningless and they are more appropriately analyzed solely as members of the larger data set. Because of difficulties in obtaining a Portuguese translation, questionnaires were not distributed to Brazil (by fax) until September 1995; at the same time follow-up faxes of the questionnaire were distributed to the larger ports for which answers had not yet been received. In all, questionnaires were returned covering 49 ports, with multiple responses received for several ports due to carrier responses. The complete list of ports for which responses were received is provided in Appendix B.

III.C.2. Port Activity and Demographic Research

Data is readily available for annual container traffic from 1980 to the present for most ports in the world with more than occasional container throughput. Annual data from 1993 for loaded containers were selected as the most recent figures for container traffic that could be comprehensively compiled. The collection of demographic data for the various hinterland regions required evaluation of sufficient questionnaires that final determination could be made on appropriate hinterland sizes. As described above in section III.B.2., atlases and references containing data on the populations of cities, counties, states, provinces, and other administrative divisions were utilized to develop population figures for hinterland area. Calculation of GRPs was then a relatively simple matter of applying per capita GDPs and incomes to each hinterland area. In all, it was possible to compile these data fully for 99 of the 122 containerports identified in the Western Hemisphere.

III.D. MODEL FORMULATION

In order to determine the relationships between landside access and seaport container movements, it was necessary to estimate a variety of linear regression equations. All models were estimated using the ordinary least squares method, utilizing the Statistical Software Tools (SST) software, version 2.0, produced by J.A. Dubin and R.D. Rivers. As mentioned previously, separate models were to be estimated for the data set for which only the port activity and hinterland variables had been compiled, as well as for those ports for which the full range of access variables were also available. Because of the enormous number of possible permutations of variables present in specifications, a set of guidelines and standards were followed to limit the number of models needed to be estimated.

In particular, a number of models containing a large number of explanatory variables were initially explored to determine which variables appeared to hold the most promise. As models were refined, specifications with about six or fewer variables were favored as allowing easier interpretations of parameter estimates and of possible interactions occurring among the explanatory variables. One of the primary reasons for this was the high degree of multicollinearity, or correlation, between the explanatory variables. With multicollinearity, parameter estimates can frequently change sign, and interpretations may vary dramatically based on complex interactions.

Based on the initial results, specifications not envisioned *a priori* were also examined for possible further insights. One of the major means in which this was accomplished was through the operationaiization of many additional variables through data transformations and the creation of alternative forms of interactive variables. Although the t-test significance levels of individual parameters and adjusted r-squared results of various models were closely monitored, improvements in these figures were by no means treated as hard criteria for the refinement of specifications. As an end result, similar, alternative versions of model specifications are frequently presented together, rather than a single model being selected as "the best," to help explain the relationship between landside access and seaport activity.

CHAPTER IV. RESULTS

This chapter presents the results of the data collection and statistical analyses conducted for this thesis. Section IV.A. first provides a summary of the raw data results from the questionnaire responses and the compilation of demographic and economic characteristics of the hinterlands. Accompanying interpretations highlight important or surprising insights found in the data. Section IV.B. presents the best set of models found among the various specifications utilized, along with their corresponding regression results. An interpretation of the parameter estimates for each specification are provided with each set of results. These parameter estimates are discussed in the context of their practical application to seaports and their utility to decision makers. Finally, section IV.C. describes some brief case studies of several seaports, applying the model results to the realities of their specific situation.

IV.A. ANALYSIS OF COLLECTED DATA

Tables IV-1 through IV-8 present a summary of the data results received and compiled, and are, in themselves, able to provide a number of insights into landside access and container activity. The tables present the average and other statistical characteristics for all ports and for a variety of cohorts based on port size or geographic location. In addition, a weighted average of the various statistics, along with a standard deviation of the data and a count of how many observations each average was based upon are presented. The weighted averages were computed with proportionality based upon the number of loaded TEUs the given port handled in 1993. The weighted average data should therefore be interpreted as showing the characteristics of maritime container traffic, rather than the characteristics of ports. Comparisons between the average and this weighted average will therefore show important insights into ports and port users.

The data in Table IV-1 shows that the average container port in the Americas handled about 250,000 TEUs in 1993, with a little more than three-quarters of them full (the regressions were estimated using this lower, loaded TEU figure as the dependent variable). The maximum, median, and minimum figures show the diversity of port sizes, with half of the ports under 50,000 loaded TEU. The cohort data from Table IV-2 shows average loaded TEUs for a variety of cohorts; the order of magnitude between the large and medium sized ports is salient. Since the weighted average figure (IV-1) indicates that only 40% of all TEUs utilize the Pacific ports, the high average figure for Pacific ports (IV-2; double the overall average annual port traffic) demonstrates that having fewer ports on the western side of the continent results in higher average traffic in each.

The hinterland population data in Tables IV-1 and IV-2 fit well with expectations and the results of the regression analyses. While all four hinterland areas showed larger average populations and GRPs for the larger ports, it was the metropolitan and local areas that showed the largest proportional differences, and the rail and trucking areas the least. This fits well with theory that closer markets are more likely to be important to ports than distant markets. Surprisingly, in the weighted average data, the local region population was actually smaller than the metropolitan figure, because the former had to be divided whenever multiple ports were located in the same metropolitan area. (This is the case for several large ports, e.g. Los Angeles, Long Beach, Oakland, Miami, Seattle, Houston, and Tacoma). The U.S. and Canadian ports' dominance in both numbers of ports and quantity of container traffic are the reason for the very large figures for average rail market population; a significant number of other ports serve much smaller rail networks, while many more have no rail access and hence a rail market of 0. Thus, while this data can be considered reliable, use of the average and/or weighted average is not a very appropriate description of a typical port's rail market, due to the heterogeneity of the data. The hinterland regional product figures follow a pattern very similar to that of hinterland population, supporting the expectation that both shed some light onto the issue of freight demand generation.

Non-coastal or "inland" ports actually show higher average TEU activity than the average for all ports, while island ports dramatically show the reverse. The former indicates that inland location is actually correlated with being a larger port, but both intuition and the regression analysis demonstrate that this figure is misleading. A number of busier ports are indeed located up estuaries (presumably due to new operating strategies and technology not yet overcoming historical patterns), but the regression analysis shows that they handle proportionally less container traffic than ports with otherwise similar characteristics located on or near the coastline. The results for island ports are unsurprising; despite the presence of San Juan and Honolulu (sixth and 15th busiest container ports in the hemisphere, respectively), the numerous very small to medium ports on Caribbean islands result in a significant drop off in the weighted average for this characteristic.

TABLE IV-1

Ports' Geography and Hinterland Characteristics

Statistical Attributes of Sample Data for All Ports

Variable	Average	Standard Deviation	Weighted Average	Maximum	80th Percentile	Median	Minimum
Sample size	99	99	18,715,806	99	99	99	99
Total TEUs, 1993	248,423	442,242	1,039,305	2,289,038	366,518	72,436	0
Non-empty TEUs, 1993	189,049	344,237	809,535	1,820,678	349,057	47,001	0
Metropolitan area popn.	1,849,865	3,651,739	6,276,595	18,701,000	2,559,000	312,368	1,478
Local region popn.	3,075,198	4,038,947	6,153,671	24,193,000	5,151,147	1,750,007	10,000
Trucking market popn.	16,612,155	19,637,106	6,153,671	75,385,073	31,244,825	9,096,367	0
Rail market popn.	56,103,991	54,479,445	94,094,466	129,767,963	112,619,963	35,611,000	0
Metropolitan area GRP ($M)	31,486	72,453	129,920	489,054	46,986	1,500	7
Local region GRP ($M)	35,749	72,106	117,314	595,529	53,435	12,774	54
Trucking market GRP ($M)	285,847	450,915	474,954	1,764,011	472,821	48,341	0
Rail market GRP ($M)	1,114,587	1,318,165	2,113,148	3,036,570	2,633,318	86,309	0
Noncoastal port (1=yes; 0=no)	0.09	0.29	0.09	1	0	0	0
Island port (1=yes; 0=no)	0.27	0.45	0.12	1	1	0	0
Pacific port (1=yes; 0=no)	0.19	0.40	0.40	1	0	0	0
US/Can. port (1=yes; 0=no)	0.53	0.50	0.85	1	1	1	0

Notes:

Definitions of variables are provided in section III.B.2.

All values, except weighted average, represent the statistical attributes for data by port.

Weighted average is the average for ports, weighted by loaded containers handled, rather than with all ports weighted equally, and thus is equivalent to the average for loaded containers, rather than the average for ports.

Eightieth percentile gives the value at which 80 percent of the ports' data are equal to or lower than the given figure.

TABLE IV-2

Ports' Geography and Hinterland Characteristics

Averages of Sample Data for Key Cohorts

Variable	Average	Top 10 ports	Top 20 ports	Large ports	Medium ports	Small ports	Pacific Coast	US/Can. ports
Sample/cohort size	99 / 99	10 / 10	20 / 20	33 / 33	33 / 33	33 / 33	19 / 19	52 / 52
Total TEUs, 1993	248,423	1,361,535	937,757	652,973	77,404	14,893	496,179	393,161
Non-empty TEUs, 1993	189,049	1,054,044	726,657	501,985	55,337	9,823	392,472	305,023
Metropolitan area popn.	1,849,865	6,476,743	5,495,491	3,916,274	1,041,233	592,088	3,289,355	2,588,937
Local region popn.	3,075,198	6,099,787	6,037,269	4,881,216	2,076,048	2,268,330	3,943,945	2,842,740
Trucking market popn.	16,612,155	26,539,890	26,445,624	20,581,595	18,792,631	10,462,239	12,691,069	22,561,397
Rail market popn.	56,103,991	107,214,267	99,530,382	80,500,008	44,937,176	42,874,787	90,730,179	84,853,479
Metropolitan area GRP ($M)	31,486	147,873	92,199	63,332	21,806	9,320	65,422	57,608
Local region GRP ($M)	35,749	135,424	94,860	70,129	18,840	18,278	48,925	60,747
Trucking market GRP ($M)	285,847	604,157	544,640	395,819	313,180	148,542	189,369	519,441
Rail market GRP ($M)	1,114,587	2,508,544	2,222,860	1,746,061	779,616	825,043	3,036,570	1,690,559
Inland port (1=yes; 0=no)	0.09	0.10	0.15	0.09	0.12	0.06	-	0.17
Island port (1=yes; 0=no)	0.27	0.10	0.10	0.09	0.39	0.33	-	0.19
Pacific port (1=yes; 0=no)	0.19	0.50	0.30	0.27	0.12	0.18	1.00	0.21
US/Can. port (1=yes; 0=no)	0.53	1.00	0.90	0.73	0.45	0.39	0.58	1.00

Notes:

Definitions of variables are provided in section III.B.2. All values are the statistical average (mean) of available data.

Size cohorts were delineated by grouping ports by number of loaded TEUs handled, with cohorts for the ten and twentiest busiest ports, as well as for each third part of the sample.

Tables IV-3 and IV-4 shed some strong insights into mode share and market share for ports, an area in which data is not often available for such a broad array of ports. The mode shares of truck and rail meet expectations in terms of rail playing a more important role at larger ports. Rail represented nearly 30% of container moves overall (seen from the weighted average) and at large ports, but the average for all ports for which data was available was a mode share of only 19.2%. US/ Canadian ports had a mode share split surprisingly similar to other ports in the hemisphere. Considered in conjunction with the break down by size cohort, this indicates that mode shares likely are based more strongly on economies of scale than on institutional differences between nations. The limited number of intermodal container moves (although drayage under 30 minutes was considered rail only) was somewhat of a surprise, but barge container moves represented the expected minimal share.

Ports provided widely varying answers to the questions about their geographical market shares; a poorly-worded survey question and the ports' own lack of data on this issue[16] resulted in data that should be treated as unreliable as a whole. Contrastingly, ports were able to provide fairly consistent data, apparently with some precision, on typical container transport distances. While the large differences across different port cohorts in moving containers more than 1000 miles was expected, it was somewhat surprising that larger ports moved nearly the same share of their containers the intermediate distance of 200 to 1000 miles than typical ports.

While the truck and rail radii (the break-even or trade-off point between the competitiveness of these two modes) should theoretically have been the same, ports frequently reported different numbers for the two radii, indicating some "gray zone" of about 100 to 150 miles in the middle of the two limits. Presumably, this is where truck and rail are equally competitive, or where the advantage between the modes is unclear or depends upon the specific circumstances. Responses for these two questions were extremely inconsistent, but larger and US/Canadian ports did show an overall tendency to use rail only after longer haul distances than medium and smaller and non-US/Canadian ports did. These distances did fall somewhat under the general North American rule-of-thumb that rail is not competitive until from 500 miles distant from a given origin.

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[16] Many ports indicated that, as requested, they were simply making guesses in answering this question. Other ports filled in this question incompletely or incorrectly, resulting in the author filling in blanks where other data allowed.

TABLE IV-3

Ports' Mode Shares and Market Characteristics

Statistical Attributes of Sample Data for All Ports

	Variable	Data points	Average	Standard Deviation	Weighted Average	Maximum	80th Percentile	Median	Minimum
	Sample size	44-49	44-49	44-49	15,514,299	44-49	44-49	44-49	44-49
Mode Share	Truck	48	75%	26%	67%	100%	100%	84%	20%
	Rail	47	19%	21%	29%	75%	40%	10%	0%
	Truck & rail	47	4%	14%	4%	85%	2%	0%	0%
	Other (barge)	47	2%	8%	1%	50%	0%	0%	0%
Market Share	Metro area	44	54%	32%	55%	100%	90%	60%	5%
	Local region	44	31%	27%	36%	100%	45%	20%	1%
Transport Distance	< 20 miles	44	25%	27%	24%	94%	35%	18%	1%
	20-200 miles	44	39%	25%	31%	90%	63%	40%	0%
	200-1000 miles	44	26%	26%	24%	99%	40%	20%	0%
	> 1000 miles	44	10%	14%	21%	50%	15%	5%	0%
	Trucking radius	49	366	317	445	1,500	600	350	24

Notes:

Definitions of variables are provided in section III.B.2.

All values, except weighted average, represent the statistical attributes for data by port.

Weighted average is the average for ports, weighted by loaded containers handled, rather than with all ports weighted equally, and thus is equivalent to the average for loaded containers, rather than the average for ports.

Eightieth percentile gives the value at which 80 percent of the ports' data are equal to or lower than the given figure.

TABLE IV-4

Ports' Mode Shares and Market Characteristics

Averages of Sample Data for Key Cohorts

	Variable	Average	Top 10 ports	Top 20 ports	Large ports	Medium ports	Small ports	Pacific Coast	US/Can. ports	Non-US/ Can. ports
	Sample/cohort size	44-49/99	9 / 10	18 / 20	16 / 16	17 / 17	16 / 16	13 / 19	36 / 52	13 / 47
Mode Share	Truck	75%	60%	66%	69%	79%	75%	64%	71%	84%
	Rail	19%	37%	29%	28%	13%	15%	28%	20%	15%
	Truck & rail	4%	4%	5%	3%	4%	5%	3%	6%	0%
	Other	2%	0%	0%	0%	3%	4%	5%	3%	0%
Market Share	Metro area	54%	54%	57%	56%	57%	49%	49%	45%	74%
	Local region	31%	32%	38%	39%	28%	25%	32%	30%	32%
Transport Distance	< 20 miles	25%	19%	22%	23%	24%	27%	24%	22%	32%
	20-200 miles	39%	28%	33%	32%	45%	41%	33%	37%	44%
	200-1000 miles	26%	26%	27%	27%	24%	27%	22%	27%	23%
	> 1000 miles	10%	27%	18%	18%	7%	4%	21%	14%	1%
	Trucking radius	366	420	393	417	307	379	412	421	231

Notes:

Definitions of variables are provided in section III.B.2. All values are the statistical average (mean) of available data. Size cohorts were delineated by grouping ports by number of loaded TEUs handled, with cohorts for the ten and twentiest busiest ports, as well as for each third part of the sample.

Tables IV-5 and IV-6 show both some disappointing and some unexpected results. Like the data on market shares, a number of ports had little or no data on terminal activities. This perhaps should have been better addressed in the data collection process, since many port terminals are operated under concession agreements or private leases, limiting the information depth of the port authority. Further, an ambiguity in the wording of the question on terminal dwell time resulted in many answers instead providing average time for the actual physical handling of containers. Consequently, this data had to be segregated by the author into dwell time and entry/exit time. None of the terminal data was considered complete or reliable enough to be used in any of the statistical modeling. Based on port authority responses, future research will need to inquire directly with terminal operators to acquire this information.

The greater degree of urban congestion in the vicinity of busier ports (average of 3.13 on a 5-point scale with 1 meaning most congested, versus 3.73 for the average port) was not surprising given their usual location in larger cities. With the degree of attention given to this problem in much of the researched literature, however, it was surprising to see that only one port was placed in the worst category and only six in the category for the second worst level of congestion. 14, 12, and 16 ports rated themselves as at congestion levels 3, 4, and 5, respectively. The fact that so few, but including some of the larger, ports rated their areas as congested appears to be a primary reason why this variable showed counter-intuitive results in the regression analysis.

As would be expected, the travel time to intercity highways shows some advantage for larger ports. However, Tables IV-5 and IV-6 illustrate that the rating of overall regional truck access for large ports (2.13) is only a marginal improvement over small ports (2.38), and is actually worse than the rating for medium sized ports (1.94)! Similarly, the weighted average of truck access ratings is not much lower than the port average, suggesting that container activity does not respond very much to differences in truck access. The lack of substantial differences in trucking characteristics between ports of different size cohorts was one of the most interesting insights from this data. There is always potential bias in surveys involving self-ranking, but the large truck access rating difference between US/Canadian and non-US/Canadian ports does lend increased credibility to the self-ranking process. This finding of a limited role for truck access continues to be exhibited in the regression analyses, where truck access issues are generally only found to be statistically significant when specifications include no other independent variables; explanatory power was extremely weak in these models.

TABLE IV-5: Ports' Terminal, Local, and Trucking Access Characteristics

Statistical Attributes of Sample Data for All Ports

	Variable	Data points	Average	Standard Deviation	Weighted Average	Maximum	80th Percentile	Median	Minimum
	Sample size	15-49	15-49	15-49	15,514,299	15-49	15-49	15-49	15-49
Terminal Access	Exit dwell time (hrs.)	25	70	67	57	360	84	72	24
	Enter dwell time (hrs.)	25	94	112	71	600	120	72	24
	Exit time (hrs.)	15	8.3	13.4	4.1	48.0	24.0	3.0	1.0
	Enter time (hrs.)	15	7.3	10.2	11.1	30.0	24.0	2.0	0.5
	Terminal costs ($)	24	161	84	175	300	260	156	50
Urban Access	Urban congest. rating	49	3.73	1.11	3.17	5	5	4	1
	Urban con. rating = 1,2	49	0.14	0.35	0.21	1	0	0	0
	Urban con. rating = 3	49	0.29	0.46	0.50	1	1	0	0
	Urban con. rating = 4	49	0.24	0.43	0.16	1	1	0	0
	Urban con. rating = 5	49	0.33	0.47	0.12	1	1	0	0
Truck Access	Time to highway (min.)	49	18	20	13	120	30	10	1
	Truck access rating	49	2.14	0.96	1.95	4	3	2	1
	Truck rating = 1	49	0.35	0.48	0.44	1	1	0	0
	Truck rating = 2	49	0.20	0.41	0.18	1	1	0	0
	Truck rating = 3-5	49	0.45	0.50	0.38	1	1	0	0

Notes:
Definitions of variables are provided in section III.B.2. All values, except weighted average, represent the statistical attributes for data by port. Weighted average is the average for ports, weighted by loaded containers handled, rather than with all ports weighted equally, and thus is equivalent to the average for loaded containers, rather than the average for ports. Eightieth percentile gives the value at which 80 percent of the ports' data are equal to or lower than the given figure.

TABLE IV-6: Ports' Terminal, Local, and Trucking Access Characteristics

Averages of Sample Data for Key Cohorts

	Variable	Average	Top 10 ports	Top 20 ports	Large ports	Medium ports	Small ports	Pacific Coast	US/Can. ports	Non-US/ Can. ports
	Sample/cohort size	49 / 99	9 / 10	18 / 20	16 / 16	17 / 17	16 / 16	13 / 19	36 / 52	13 / 47
Terminal Access	Exit dwell time (hrs.)	70	48	52	50	58	103	55	49	125
	Enter dwell time (hrs.)	94	52	73	62	81	140	69	62	175
	Exit time (hrs.)	8.3	2.5	3.3	3.3	7.2	11.1	4.0	7.9	8.8
	Enter time (hrs.)	7.3	12.5	9.0	9.0	7.7	6.3	24.0	9.8	3.5
	Terminal costs ($)	161	215	165	180	137	167	187	155	170
Urban Access	Urban congest. rating	3.73	3.11	3.22	3.13	3.71	4.38	3.69	3.89	3.36
	Urban con. rating = 1,2	0.14	0.22	0.22	0.25	0.12	0.06	-	0.09	0.29
	Urban con. rating = 3	0.29	0.56	0.44	0.44	0.35	0.06	0.54	0.31	0.21
	Urban con. rating = 4	0.24	0.11	0.17	0.19	0.24	0.31	0.23	0.23	0.29
	Urban con. rating = 5	0.33	0.11	0.17	0.13	0.29	0.56	0.23	0.37	0.21
Truck Access	Time to highway (min)	17.86	9.44	13.03	13.41	19.09	21.00	12.58	10.33	36.68
	Truck access rating	2.14	1.89	2.00	2.13	1.94	2.38	2.00	1.83	2.93
	Truck rating = 1	0.35	0.44	0.44	0.38	0.47	0.19	0.31	0.49	-
	Truck rating = 2	0.20	0.22	0.11	0.13	0.18	0.31	0.38	0.23	0.14
	Truck rating = 3-5	0.45	0.33	0.44	0.50	0.35	0.50	0.31	0.29	0.86

Notes:
Definitions of variables are provided in section III.B.2. All values are the statistical average (mean) of available data. Size cohorts were delineated by grouping ports by number of loaded TEUs handled, with cohorts for the ten and twentiest busiest ports, as well as for each third part of the sample.

The rail access data presented in Tables IV-7 and IV-8 falls very much in line with expectations and provides strong support regarding the importance of landside access to container port activity. Unlike the very small improvement in the truck access rating in the weighted average, the rail access rating decreased (improved) from 2.76 to 1.89, and the double-stack rating decreased from 3.18 to 1.89. These numbers indicate that container activity certainly seems to be associated with ports with good rail access. Comparing average figures across the size-based cohorts, it is clear that busier ports are substantially more likely to have better rail access, and especially better double-stack service. The non-US/Canadian ports' data is extremely consistent with the common wisdom that rail is not yet a substantial factor at most Latin American container ports.

The figures on the number of rail terminals serving a port also indicated significantly better rail access for larger ports. This factor is important in terms of acting as a proxy for the number of railroads serving the port, which can have strong implications both in terms of competition between railroads and overall rail network access. Surprisingly, average drayage times actually were worse for the larger ports, perhaps due to greater congestion and/or a greater number of container berths to be served by a given railyard.

TABLE IV-7: Ports' Rail Access Characteristics

Statistical Attributes of Sample Data for All Ports

Variable	Data points	Average	Standard Deviation	Weighted Average	Maximum	80th Percentile	Median	Minimum
Sample size	43-49	43-49	43-49	15,514,299	43-49	43-49	43-49	43-49
Rail terms	49	1.65	1.30	2.68	6	3	1	0
Rail drayage time	43	12.2	12.3	14.4	60	20	5	0
Rail access rating	49	2.18	1.50	1.68	6	4	2	1
Rail rating = 1	49	0.31	0.47	0.61	1	1	0	0
Rail rating = 2	49	0.12	0.33	0.10	1	0	0	0
Rail rating = 3	49	0.22	0.42	0.14	1	1	0	0
Rail rating = 4	49	0.16	0.37	0.10	1	0	0	0
Rail rating = 5	49	0.06	0.24	0.01	1	0	0	0
Rail rating = 6	49	0.12	0.33	0.04	1	0	0	0
Double-stack rating	49	3.20	1.78	1.90	5	5	4	1
D-S rating = 1	49	0.31	0.47	0.58	1	1	0	0
D-S rating = 2	49	0.12	0.33	0.22	1	0	0	0
D-S rating = 3	49	0.06	0.24	0.04	1	0	0	0
D-S rating = 4	49	0.08	0.28	0.03	1	0	0	0
D-S rating = 5	49	0.43	0.50	0.12	1	1	0	0

Notes:
Definitions of variables are provided in section III.B.2. All values, except weighted average, represent the statistical attributes for data by port. Weighted average is weighted utilizing loaded containers handled, and thus is equivalent to the average value per loaded container, rather than the average per port. Eightieth percentile gives the value at which 80 percent of the ports' data are equal to or lower than the given figure.

TABLE IV-8: Ports' Rail Access Characteristics

Averages of Sample Data for Key Cohorts

Variable	Average	Top 10 ports	Top 20 ports	Large ports	Medium ports	Small ports	Pacific Coast	US/Can. ports	Non-US/ Can. ports
Sample/cohort size	49 / 99	9 / 10	18 / 20	16 / 16	17 / 17	16 / 16	13 / 19	36 / 52	13 / 47
Rail terms	1.65	2.78	2.61	2.38	1.71	0.88	2.08	1.94	0.93
Rail drayage time	12	13	14	13	13	10	13	12	10
Rail access rating	2.92	1.44	2.06	2.19	2.71	3.88	2.38	2.54	3.86
Rail rating = 1	0.31	0.78	0.50	0.44	0.35	0.13	0.38	0.43	-
Rail rating = 2	0.12	0.11	0.17	0.19	0.06	0.13	0.15	0.14	0.07
Rail rating = 3	0.22	-	0.22	0.25	0.24	0.19	0.23	0.11	0.50
Rail rating = 4	0.16	0.11	0.06	0.06	0.29	0.13	0.15	0.17	0.14
Rail rating = 5	0.06	-	-	-	-	0.19	0.08	0.06	0.07
Rail rating = 6	0.12	-	0.06	0.06	0.06	0.25	-	0.09	0.21
Double-stack rating	3.20	1.22	1.94	2.00	3.41	4.19	2.69	2.51	4.93
D-S rating = 1	0.31	0.78	0.56	0.56	0.24	0.13	0.46	0.43	-
D-S rating = 2	0.12	0.22	0.22	0.19	0.12	0.06	0.15	0.17	-
D-S rating = 3	0.06	-	0.06	0.06	0.12	-	-	0.09	-
D-S rating = 4	0.08	-	0.06	0.06	0.06	0.13	-	0.09	0.07
D-S rating = 5	0.43	-	0.11	0.13	0.47	0.69	0.38	0.23	0.93

Notes:

Definitions of variables are provided in section III.B.2. All values are the statistical average (mean) of available data. Size cohorts were delineated by grouping ports by number of loaded TEUs handled, with cohorts for the ten and twentiest busiest ports, as well as for each third part of the sample.

The summary results of the collected data, presented in these eight tables, provide some interesting insights into the issues, but conclusions must be drawn with caution when looking only at averages. The explicit identification of poor, unreliable data elements was one of the most significant benefits of this process. Furthermore, the development of further understanding about this data set and the relationships between access and seaport activity greatly aided in the specification and interpretation of the models below.

IV.B. REGRESSION PARAMETER ESTIMATION RESULTS

A series of regression models were estimated correlating seaport activity with hinterland population, economic activity, geographic location, and landside access measures. All models were estimated utilizing the Statistical Software Tools (SST) software, version 2.0, produced by J.A. Dubin and R.D. Rivers. With the exception of the occasional usage of a log-linear (which used the natural log of TEU) or a modified quadratic (which used the square root of TEU) specification, all models utilized loaded TEU as the dependent variable for the regressions using the ordinary least squares method.

The development of specifications followed a balance between attempting to improve the model's fit to the data, while staying within the constraint of always using specifications that make inherent sense in describing the relationship being modeled. Thus, any specification with even a single variable with a coefficient of the wrong sign (based on the theory and expectations explained in section II.B.) was eliminated, unless retained for purely illustrative purposes. Development of specifications then followed through a long, iterative process of adding and subtracting variables to prior specifications, with retention in the model based largely on statistical significance of the t-statistics. A constant factor was utilized initially in all specifications. However, it was eliminated in a number of the final models because of statistical insignificance and adverse effect on other variables, and because of cases (e.g., a negative coefficient) where the constant's parameter result might have undesirable theoretical repercussions for the model (by predicting some ports to have negative container activity, for example).

Overall, the model estimation results provide a number of good specifications that could be used, but no one clearly superior formulation of the relationship. And while a number of models were able to explain a high percentage of the variation in container activity, significant problems still remain with many of the estimated models. The high degree of multicollinearity, to be expected with series of population, economic, and transport variables, led to substantial problems in trying to formulate more all-inclusive specifications. Because multicollinearity between the explanatory variables results in parameters that cannot be reliably interpreted, the desired specifications could not always be estimated. Additionally, large ports were usually underestimated, and small ports overestimated, utilizing any of the specifications developed in this study with the 99 port or 49 port data set

Despite the above concerns, up to 74% of the variation in the data could be explained with the appropriate specifications utilizing landside access measures and the smaller data subset. While no single specification of the model stood out, application of a series of the simpler specifications should provide a series of estimates that together represent a fairly good indicator of what expected activity should be at a given port. Examples of some of the best models are presented below, while a more comprehensive set of illustrative model estimations is provided in Appendix C along with some basic interpretations of the parameters.

Selected "best" models:

(1) ********* ORDINARY LEAST SQUARES ESTIMATION *********

Dependent Variable: teu

Independent Variable	Estimated Coefficient	Standard Error	t-Statistic
one	7.80905e+004	2.46459e+004	3.16850
metgrp	2.95954	0.45754	6.46844
metpopsq	1.06928e-009	5.73999e-010	1.86285
Number of Observations		99	
Corrected R-squared		0.57449	

(2) ********* ORDINARY LEAST SQUARES ESTIMATION *********

Dependent Variable: teu

Independent Variable	Estimated Coefficient	Standard Error	t-Statistic
one	2.51741e+004	3.24253e+004	0.77637
metpop	4.25337e-002	9.22223e-003	4.61209
locgrp	1.18503	0.49678	2.38542
railgrp	3.84257e-002	2.10237e-002	1.82773
Number of Observations		99	
Corrected R-squared		0.50579	

(3) ********* ORDINARY LEAST SQUARES ESTIMATION *********

Dependent Variable: teu

Independent Variable	Estimated Coefficient	Standard Error	t-Statistic
metgrp	2.40691	0.50717	4.74575
metpopsq	1.43494e-009	5.71378e-010	2.51137
inland	-1.60621e+005	8.07800e+004	-1.98837
west	1.09740e+005	5.47882e+004	2.00299
uscan	1.41100e+005	3.89419e+004	3.62334
Number of Observations		99	
Corrected R-squared		0.61549	

(4) ********* ORDINARY LEAST SQUARES ESTIMATION *********

Dependent Variable: teu

Independent Variable	Estimated Coefficient	Standard Error	t-Statistic
metpop	7.00530e-002	8.07804e-003	8.67202
ds12g	0.11906	2.18294e-002	5.45406
Number of Observations		49	
Corrected R-squared		0.72906	

(5) ********* ORDINARY LEAST SQUARES ESTIMATION *********

Dependent Variable: teu

Independent Variable	Estimated Coefficient	Standard Error	t-Statistic
metpop	3.78230e-002	2.03148e-002	1.86185
metgrp	1.69006	0.91426	1.84855
rail1g	0.11222	2.67806e-002	4.19041
rail23g	7.23536e-002	2.96233e-002	2.44245
Number of Observations		49	
Corrected R-squared		0.71200	

The statistical analysis provided strong support for several of the *a priori* expectations about the results, while little to no statistical evidence was found for other expectations. The results buttress common notions regarding the importance of local markets, rail access, and economies of scale. Ports located in metropolitan areas with large populations and substantial economic activity (as measured by gross regional product) were likely to attract substantial cargoes. Additionally, good rail access, especially double-stack access, to large markets proved to be a significant factor in determining seaport activity. Surprisingly, little support was shown for traditional views on the importance of being near major inland markets. As was suggested by the earlier review of the data, truck access ratings did not generate a statistically significant influence on the results. Urban congestion and drayage times, frequently considered significant impediments to port efficiency, also demonstrated little consistent effect on the quantity of containers attracted to a seaport.

Interpretation of parameters

The metropolitan area hinterland demographic and economic variables, or MET variables, were all found to be significant in a variety of specifications. T-statistics for specifications of each individually with just a constant provided t-stats of 11.3, 8.9, and 8.1, respectively for these hinterland variables. METGRP usually had coefficient values of around 3 and METPOP around .07 when they were the only metropolitan hinterland variable in a specification; these values dropped approximately in half in specifications where they were both present. These values indicate that, for example, a constant term of around 72,000 plus .063 times the METPOP will give a very quick ballpark figure for annual container activity at a given seaport.[17] The METPOP coefficient here indicates that for every 1000 person increase in a metropolitan area's population, the local seaport will experience an increase of 6.3 TEU per year. Similarly, a coefficient of 3.0 for METPOP indicates that for every million dollar increase in the metropolitan area economy, seaport activity will increase by 3 TEU per year. In general, the inclusion of one or two of two of these variables greatly increased the explanatory power of any other specification, and they were found to be critical components of any model of seaport container activity.

The related metropolitan area-focused variables for congestion, however, showed little consistent statistical significance. Many times the coefficients would be of the incorrect sign, and often CON12 would have a higher coefficient than CON345, implying that increased urban congestion (not necessarily port traffic) was correlated with increased container throughput. As discussed above, because very few ports rated their areas as very congested, and several of these were larger ports, this variable may be reflecting, for example, city size, rather than congestion, and thus give these counter-intuitive results.

LOCPOP and LOCGRP, particularly the latter, showed statistical significance in some specifications. However, they were generally not robust enough to demonstrate significance in more comprehensive, inclusive specifications. Very much as expected, the values for their coefficients are somewhat lower than those for METPOP and METGRP in analogous specifications. This is due in part to their larger average values (meaning a proportionately lower coefficient will predict an equal amount of container activity). It is also because, for example, the LOCPOP's greater average distance from the port than the METPOP is associated with a relatively higher transport cost to the port, and a relatively lower transport cost to other ports. Therefore the port should capture a lower market share of LOCPOP than of METPOP, and so on as distances increase.

As mentioned earlier, the trucking hinterland areas and access rating variables seemed to show little correlation with container activity. TRKPOP and TRKGRP showed shockingly little statistical significance in this study. The trucking access ratings, whether operationalized as indicator or interactive variables, vary rarely showed any significance, and there was often a problem where the coefficients for TRK1 and TRK2, representing better access, were lower than the coefficient for TRK3. Although TRKGRP was significant when estimated with a constant term as the only independent variable, it also appeared as statistically significant in several other specifications, but with a

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17 This very simple specification explains only about 45% of the variance of the data, and can be found in its full form in Appendix C.

negative coefficient! Estimation efforts had been previously made with the TRK variables defined to include rather than exclude METPOP/METGRP, and somewhat better, but still very poor results were obtained. The objective of this thesis was to determine if a useful statistical model of the relationship between landside access and seaport container activity could be operationalized.

One explanation may be that the operationalization of the LOC variables better captures the area in which trucks are competitive from any given port. Although 500 miles is a rule of thumb for the break-even point between rail and truck, ports on average win only very small market share in the 200 to 500 mile range. Using the weighted average data in Table IV-3 and the "500 mile rule," one can see that 24% of TEUs travel less than 20 miles from the port, 31% from 20 to 200 miles, 29% travel by rail (more than 500 miles), and thus only 16% (or on average 30,000 TEUs) travel between 200 and 500 miles from a port. Yet this area has an average population of perhaps 13 million, meaning only one TEU per 429 residents, versus one TEU per 52 residents in the LOC hinterland.[18] Likely, many ports are competing with trucks for the 200 to 500 mile market, and a large part of that region for any given port may actually fall within the LOC or MET hinterland of other ports. On the other hand, the LOC area by definition includes only that area with an inherent distance/transport advantage to the given port. A summary interpretation of this argument is that the author's operationalization of the LOC and TRK variables may implicitly incorporate landside access advantages into the hinterland data through the explicit definition of the LOC area.

The results with the truck variables are critical, because their statistical insignificance indicates that either this thesis failed to operationalize those variables successfully, or that quality of trucking access truly is not a statistically significant factor in port traffic. Likely, some combination of both is true. Given that a nearly identical subjective rating scale for rail, judged by the same individuals, provided very good insights at a statistically significant level, the operationalization hopefully is not too far off the mark.

Good rail access to large, distant markets was also found to be one of the most dominant factors in determining seaport activity. While RAILPOP and RAILGRP were often significant, they rarely had more than a marginal impact on the explanatory power of the models they were in. However, the rail access ratings and double-stack access ratings, both as indicator variables and, especially, as interactive variables, were of great use in developing the better

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18 These calculations unavoidably exaggerate the numbers slightly, since the LOCPOP hinterland frequently does not extend out as far as 200 miles. Nonetheless, the adjustments necessary to account for this inaccuracy would not substantially alter the large discrepancy in these market share figures.

models of container activity. In particular RAIL1, RAIL2, RAIL3, DS1, and DS2 consistently appeared as significant independent variables. While the lower rail and double-stack access ratings were sometimes statistically significant, they rarely had much explanatory power and were of questionable significance in models with higher r-squared's. The better rail access variables were usually most powerful when operationalized as interactive with RAILGRP, and RAIL2/RAIL3 and DS1/DS2 were often transformed into single, combined variables because the estimated coefficients and standard errors of the two components were usually very similar. Because the data values were identical for these variables, their coefficients are directly comparable. DS12G frequently had a coefficient value of 0.11 to 0.12, RAIL1 a value of 0.10 to 0.11, and RAIL23 a value of 0.07 to 0.08. Here, a coefficient of 0.10 signifies that a $10 million increase in economic activity in the rail hinterland will increase port activity by one container per year. These relative values are consistent with expectations: since double-stack service is in effect an enhanced form of rail, the ordering of coefficient values matches that of quality of landside access by rail. Additionally, the values are comparable with those of METGRP and LOCGRP; the coefficient values ranging from one-tenth to one-fortieth the size of those for the near hinterland variables appears to be a solid result.

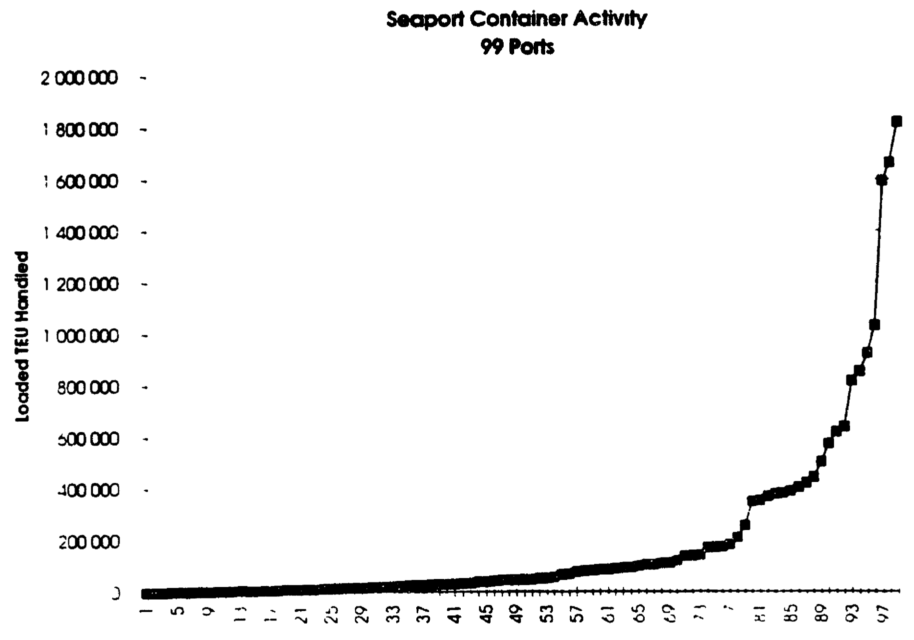
As discussed earlier, non-coastal or INLAND ports are intuitively expected to be adversely affected by the higher costs and longer transit times for ocean carriers to serve them. The coefficient for this variable was correspondingly negative, and it was frequently statistically significant or on the verge of being so. Perhaps because of the few number of data points, however, this variable (and, indeed, all of the geographic indicator variables except USCAN) did not have a lot of explanatory power. The results for ISLAND were varying positive/negative coefficients and little statistical significance. This was at least consistent with the uncertain expectations about what the effect of geographic isolation would be. USCAN was expected to capture the effects of the North American proximity to Europe and Japan and the beneficial institutional and regulatory environment of the United States and Canada. While it had both statistical significance and noticeable affect on r-squared when no rail variables were present in the specification, its usefulness dramatically declined in models with rail access rating variables. Thus, it appears that this variable was functioning as much or more as a proxy for this region's relative preponderance of rail as for its intended purpose. The WEST variable was fairly significant and did help the explanatory power of the models somewhat. Its coefficient values ranged from 70,000 to 140,00 when significant, which appears to be a reasonable figure to reflect the beneficial effects of the west coast's relative port scarcity resulting in each attracting more traffic on average.

Data and specification problems
For all model specifications in which residuals were evaluated, the linear estimation technique underestimated the activity at large ports and overestimated the activity at smaller ports. The most likely explanations for this include "load-centering," or calling fewer ports to increase vessel utilization rates, the concentration of port calls in the same ports by legally colluding ocean carriers, and port economies of scale. These factors represent possible non-linearities that are more difficult to model utilizing statistical methodologies. However, multiple attempts to correct for this were unable to do more than provide additional insights into a diagnosis of the problem.

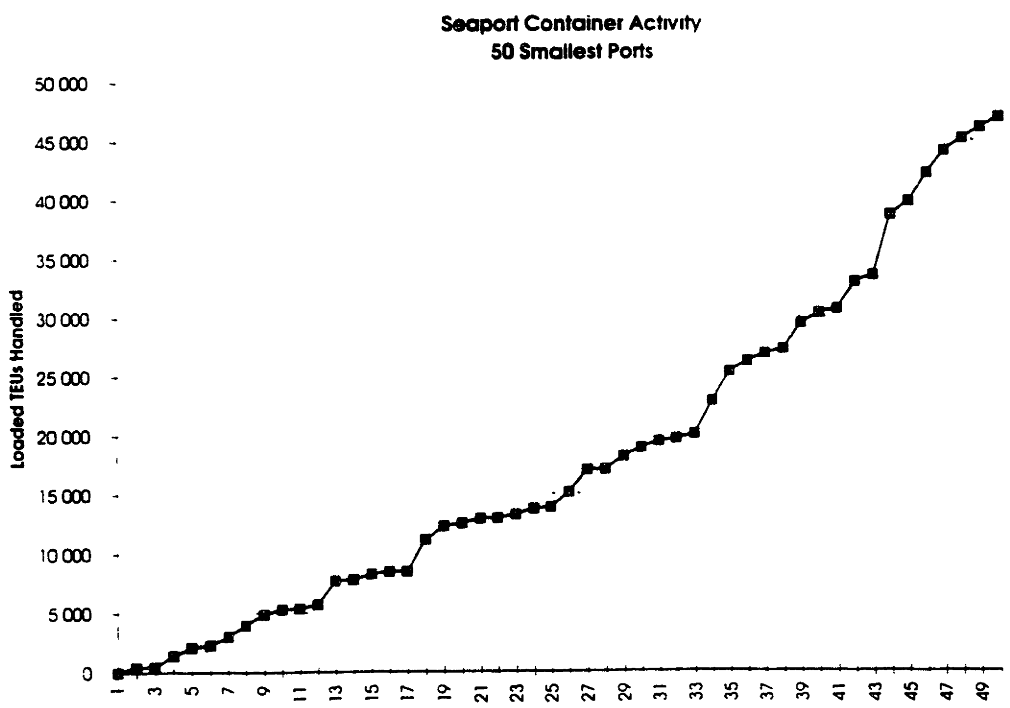
Log-linear and quadratic forms were specified in a number of ways for a variety of variables. While they sometimes improved the appearance of the residuals, they did so at substantial cost to the explanatory power of the models. Since the underlying small port / big port bias still existed with these specifications, they were not pursued for final models. The use of a proxy variable and interactive variables based upon it to represent a structural break in the data demonstrated that this was the primary problem with the data set. However, although it greatly improved the explanatory fit of the model, there was no compelling theoretical or analytical justification for choosing any given break-point as appropriate for a structural change in the model. So while either estimating the model with structural change variables or completely segregating the model into size cohorts removed the estimation problems of bias in the residuals, this technique worked similarly well whether the break was placed at 50,000 or 250,000 TEU's, or anywhere in between.

The other notable point about estimating separate models was that, when ports were segregated into a group of all ports under 70,000 TEU (or any lower number), no reasonable specification had any explanatory power (r-squared's were less than .06!). The pattern for the small ports is uncorrelated with any of the independent variables, and indicates that the methodology taken in this thesis is unsuitable for small ports. This may indicate either a lack of precision in the model, or that once below a certain level, port size is more or less "randomly" distributed based on such a wide variety of factors as to make statistical modeling inappropriate. A plot of the TEU data for small ports shows a straight linear pattern of port size, while that for the entire data set is an exponential pattern:

Figure IV-1



Seaport Container Activity
99 Ports
Loaded TEU Handled
2 000 000
1 800 000
1 600 000
1 400 000
1 200 000
1 000 000
800 000
600 000
400 000
200 000
0



Seaport Container Activity
50 Smallest Ports
Loaded TEUs Handled
50 000
45 000
40 000
35 000
30 000
25 000
20 000
15 000
10 000
5 000
0
1
3
5
7
9
11
13
15
17
19
21
23
25
27
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As mentioned previously, a high degree of correlation between many of the explanatory variables (multicollinearity) was apparent in some of the data, as would be expected given the strong relationship between population, economic activity, and transportation infrastructure. This proved somewhat problematic in developing model specifications, as variables would frequently exhibit counter-intuitive parameters due to complex interactions. Also, there is always some danger of data unreliability in using survey results when respondents are giving subjective ratings of themselves. This may have been one factor in some of the unexpected results seen for the congestion and trucking access variables.

Chapter conclusions

These models, and the other models estimated, can provide a variety of insights into the relationship between landside access and seaport activity. One of the primary conclusions to be drawn from the various models was that a large, local metropolitan area was determined to be a critical issue in seaport activity. Various specifications found good fits for metropolitan population, metropolitan GRP, and the square of metropolitan population, and often for two of these factors. This indicates that carriers pay substantial attention to making their port calls in the largest markets, and they then try to concentrate their activity in these locales to maximize asset (ship) utilization and to take advantage of economies of scale.

CHAPTER V. CONCLUSIONS

This work was generally successful in developing a set of models of the relationship between access and seaport container activity. While a variety of models with sound independent variables and good explanatory power were estimated, few of the explicit measures of physical landside access were present in the best models. Nonetheless, most of the access variables considered were found to be significant and to display results consistent with expectations in models of lesser explanatory power, and access was implicit in the way the hinterland variables were operationalized. Various decision-makers will find application for the model as a general benchmarking tool that is quick, easy, and inexpensive to use.

Of course, the models developed here are not capable of nor intended for making judgments regarding specific landside access investment decisions. These models only reflect the level of container throughput, and thus ignore efficiency gains that might be made by access improvements. And because of the limited geographic scope of the data and the imperfections of data collection, even where the appropriate variables are available the judgments that can be reached on both the feasibility and effectiveness of landside access enhancements are not definitive. Despite these caveats, the results developed here strongly suggest that, in the proper broader context, rail enhancements including double-stack access deserve much of the positive attention that they have received over the past decade, while truck access, especially to markets an intermediate distance away, on average is not very important in attracting container cargo.

Because statistical models such as this should only be viewed as providing generalizations, it is important to try and expand the scope of this model geographically and temporally in order to increase confidence in the more universal applicability of results. Additionally, the operationalization of several variables should be explored in order to include explicitly a broader set of access issues than is present in the current best models estimated. The results and methodology presented here should provide sufficient guidance for substantial future research and data collection efforts, as well as for further refinement of the variable operationalization and model estimation conducted here.

V.A. IMPLICATIONS OF RESULTS

The development of a data set of port activity, demographic and economic characteristics of hinterlands, transportation quality and availability, and related accessibility measurements suitable for statistical analysis was one of the primary challenges of this research. The most problematic aspect of the data collection effort was expected to be the gathering of landside access measures. While the overall response rate for the questionnaire gathering this data was satisfactory, several potentially important question areas did not receive sufficient admissible responses to be utilized in the formal analysis. Despite these shortcomings, the ability to estimate numerous insight-giving model specifications means that the data collection efforts can be viewed an overall success.

Based on the data and results generated in this thesis, a number of entities may benefit in pursuing some of their port-related policy objectives. International development organizations such as the World Bank actively seek out benchmarks and broad sectoral indicators in order to facilitate their measurement of countries' relative development and areas of need. These broad measures help advance the debate of higher level policies, such as when scarce resources are trying to be allocated across an entire continent, or even between continents. Thus, these results may provide a useful general performance indicator for seaports by applying the model results to determine cases of particularly poor performance. Additionally, by demonstrating the feasibility of this approach, a more informed decision can be undertaken on whether to conduct a larger research and data collection in order to expand and refine the model for more comprehensive application.

National governments may benefit from the model by gaining additional insights into the number and, especially, the total throughput capacity of container ports needed to efficiently serve their economy. In cases where there are national maritime policies, they may also draw several important conclusions from the model results in terms of implementation of various landside access investment strategies. In particular, it is suggested that, in cases where there are large hinterland markets beyond the efficient range of trucking for ports on the same coast, decision-makers may want to focus investment in rail access, especially double-stack rail, rather than truck access improvements, on a few ports selected as load-centers or otherwise targeted for growth. Of course, this model would only be one element of any debate on such policies, but it nonetheless does provide additional insight into these issues.

Finally, state, regional and local port authorities may find use in the results in terms of benchmarking and investment policy. Application of the models to give a range of reasonable figures of port activity sets at least some sort of objective standard upon which individual ports may be judged, rather than relying solely on comparisons with nearby competitors. For example, few ports explicitly consider the size of their own (or competitors') metropolitan area population and economy when comparing themselves with the TEU activity or nearby or competing ports; however, this should be one of the most important factors in their evaluation. The previously mentioned issue of investment in rail versus truck access also gives some insights from these results to port authorities. However, the conclusions of this analysis are not robust enough regarding landside access to be a basis for decision-making at the individual port level. Certainly traditional techniques are much better suited for that level of analysis.

Lastly, there are some interesting implications to consider these results in the context of port marketing. When one looks at ports' ads in trade magazines, rarely does one see claims such as: "Georgia Port Authority: Providing the best service to Savannah and New Brunswick," or even, "Delaware River Port Authority: Your best access to the six million people in the Philadelphia-Wilmington metropolitan area." Increasingly, one also now sees advertisements exclaiming double-stack access to more distant markets. But usually, what one sees are regional maps, with radii usually drawn at, say, 250, 500, and 750 miles, highlighted by headlines such as "JAXport: best to the Southeast," "Baltimore: closest to the Midwest," or "Port of New Orleans - your port for the Gulf Coast." The results of the parameter estimations conducted here illustrate that marketing ports for their regional trucking access may actually be the least effective market segment to target.

V.B. FUTURE DIRECTIONS

Many of the results of this analysis are not of broad enough scope for the full benefits of the results to be implemented or for undisputed interpretations regarding parameter estimates to be given. This lack of clear-cut conclusions is useful, however, as both an important result in itself and as an indicator of which directions of further research may be most useful. Further development of statistical models are seen to be an area that provides some new insights into landside access to seaports.

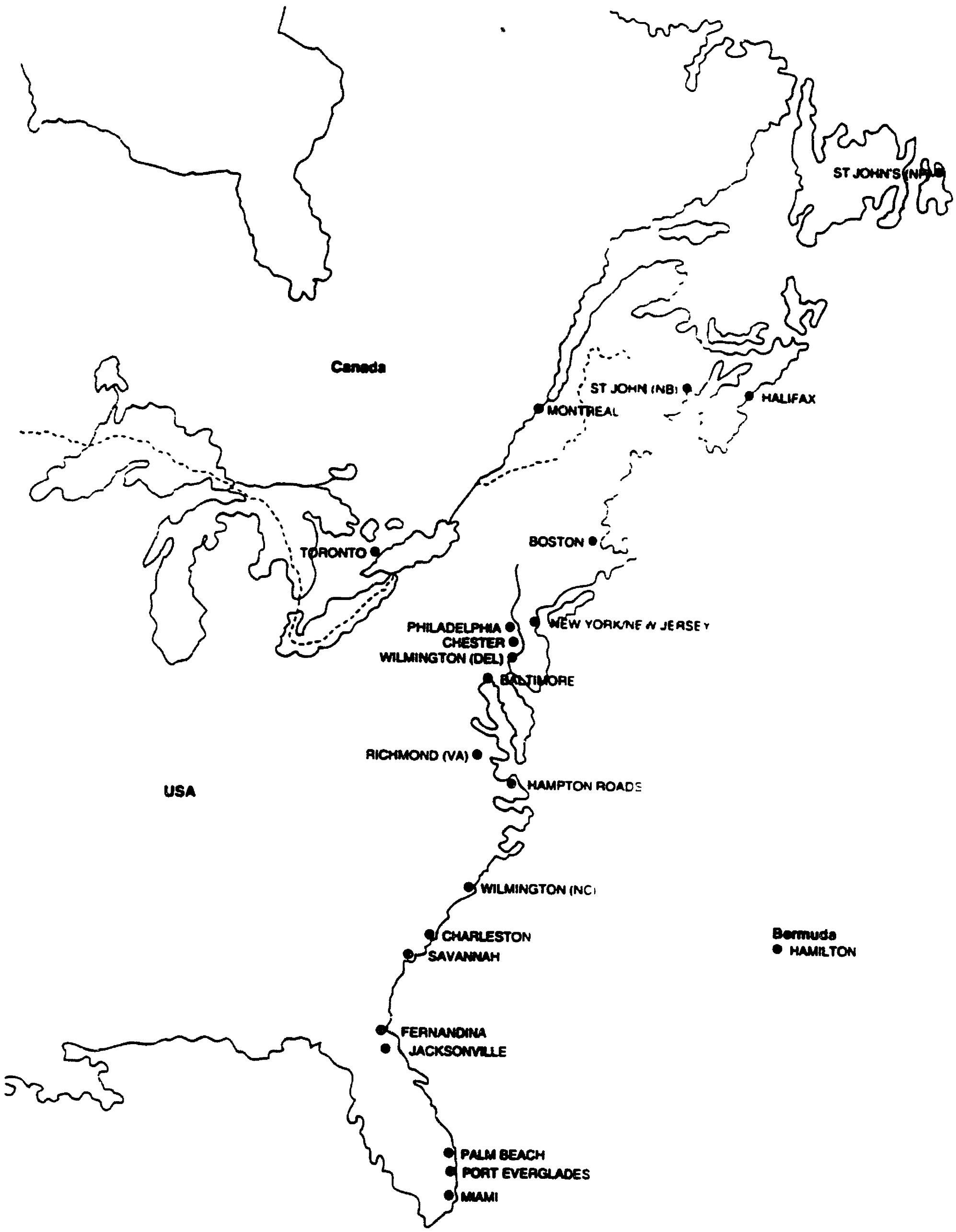
In order to accomplish better the objective of insuring the generalization of the results of this paper, other types of cargo activity should be introduced into the data collection and modeling. However, this may require a much more difficult data collection process, and such a model would likely be much harder to operationalize than the one developed here. While the range of nations and variables considered was intended to control for exogenous factors such as political events, economic structure, etc., no case study analysis was conducted to attempt to explain outliers. Data could be collected on a more global basis worldwide, perhaps including just teu and the hinterland area variables, in order to determine if the results still hold and the model explains seaport activity as well. Because the model has very little explanatory power for very small ports, it may be useful to exclude data for all ports below a certain threshold size. If possible, it would be beneficial to exclude transshipped containers from the teu data. Additionally, there may be a need to refine the landside access measures and redefine the truck and local hinterlands variables used here. Future research will need to inquire directly to terminal owners/operators to acquire information regarding their operations. The presence of substantial multicollinearity also indicates that subsequent statistical analysis will require very comprehensive data collection if more precise results are to be generated.

Chapter conclusions

Statistical models have been demonstrated to be an effective tool for estimating seaport container activity based on access to hinterlands. However, their usage should probably be limited to benchmarking type purposes, and not for individual investment decision-making. While these results may serve as a supplement to the existing tools for comparing and examining the role of multiple, diverse seaports in a broader, longer-term context, further broadening and refinement of the model is desirable, especially regarding trucking access and explicit indicators of physical transport access. In summary, this paper has provided the specific operationalization of statistical modeling techniques for seaport container activity, some general conclusions regarding the influence of landside access to various hinterlands, and a structure upon which to base future research and data collection efforts.

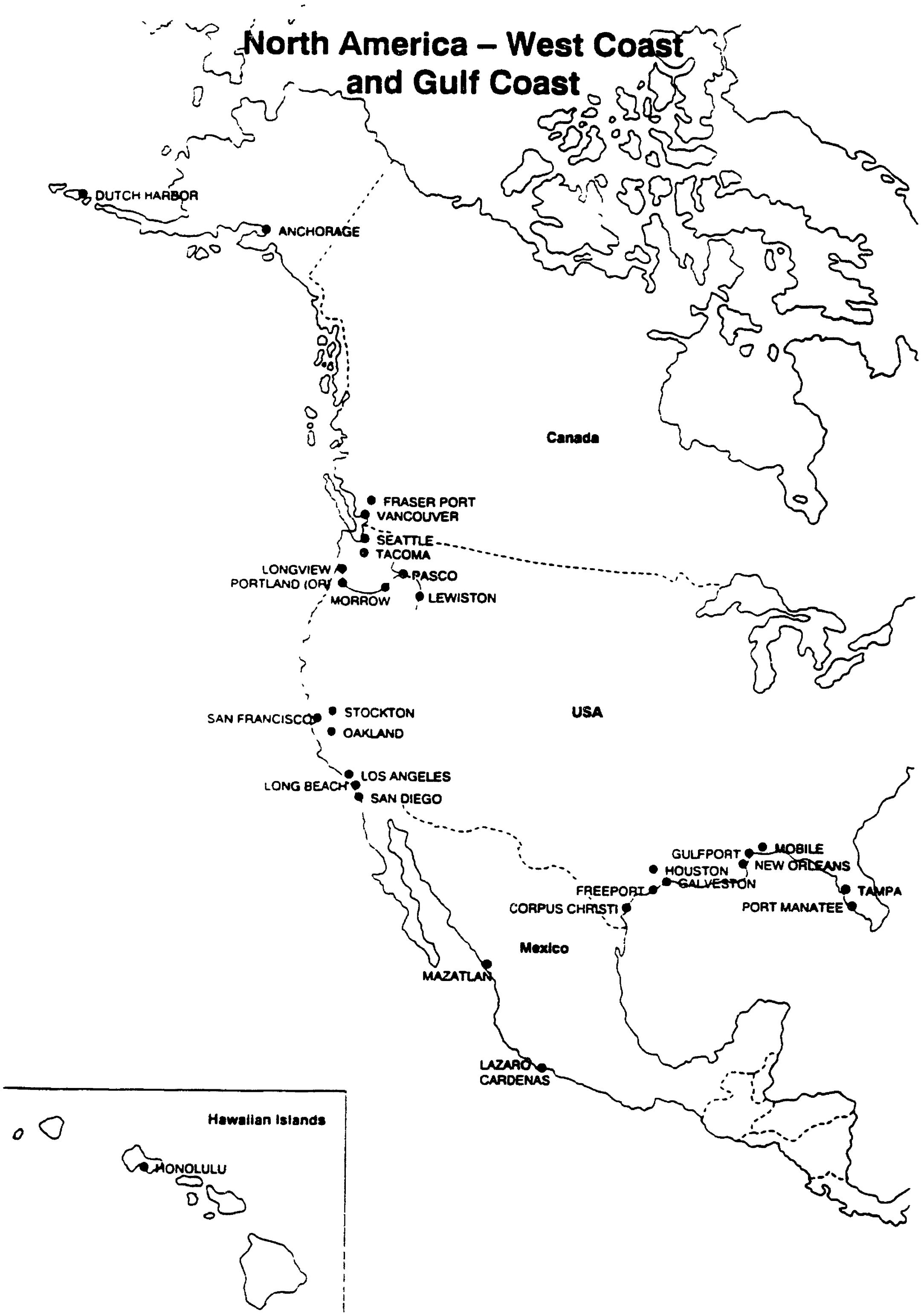
Appendix A

Maps of Ports of the Western Hemisphere



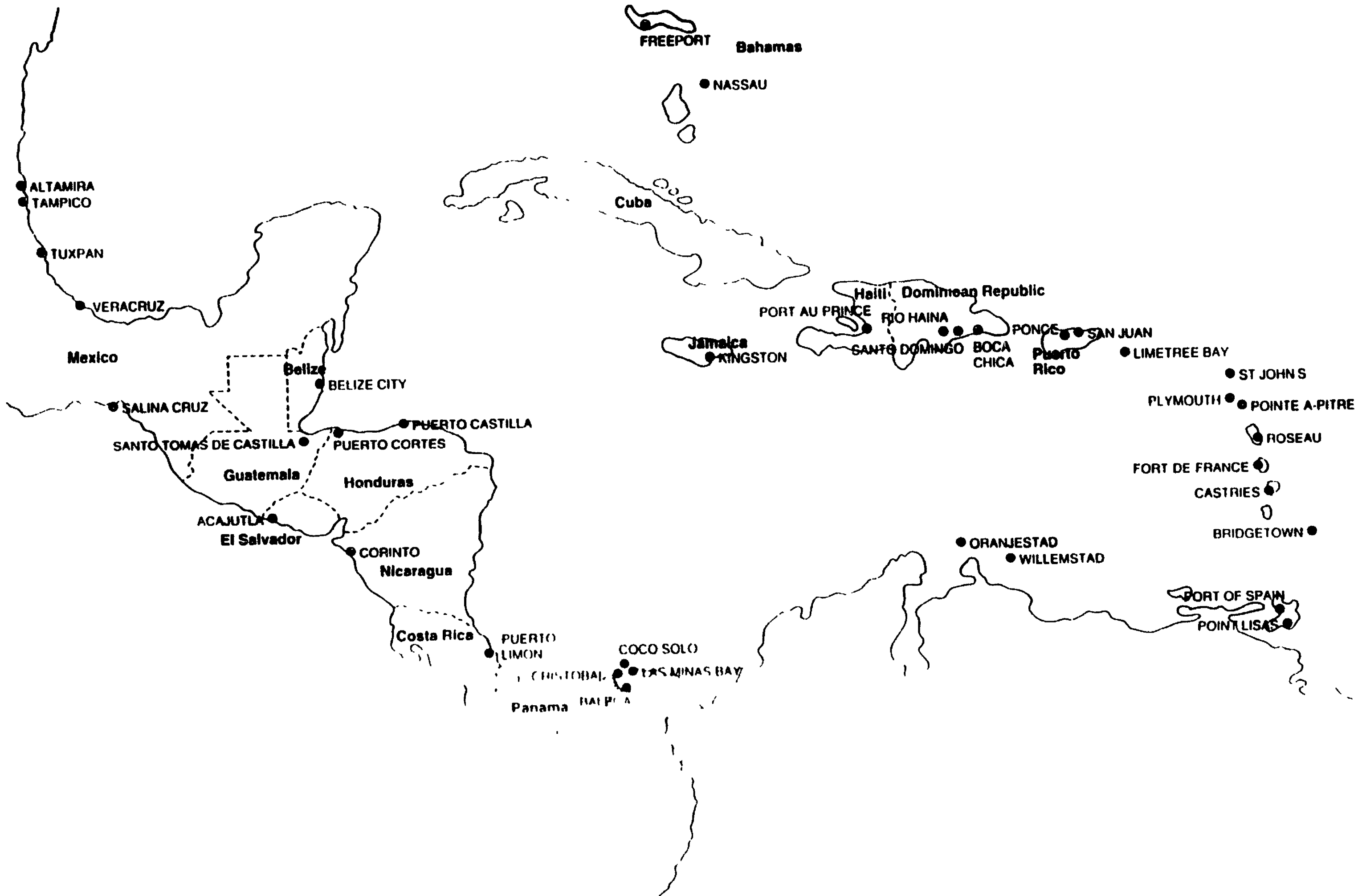
North America – East Coast
St Lawrence and Great Lakes

Source: *Containerisation International Yearbook 1995*



Source: *Containerisation International Yearbook 1995*

Source: *Containerisation International Yearbook 1995*



Central America and Caribbean

Source: *Containerisation International Yearbook 1995*

Appendix B

Questionnaires and Data Collection

Questionnaires were received from ports and/or carriers regarding the following ports:

Balboa (Panama)
Baltimore (Maryland)
Belize (Belize)
Boston (Massachusetts)
Buenos Aires (Argentina)
Charleston (South Carolina)
Corinto (Nicaragua)
Cristobal (Panama)
Fraser River (British Columbia)
Galveston (Texas)
Gulfport (Mississippi)
Halifax (Nova Scotia)
Hampton Roads (Norfolk)
Honolulu (Hawaii)
Houston (Texas)
Jacksonville (Florida)
Lazaro Cardenas (Mexico)
Long Beach (California)
Los Angeles (California)
Manatee (Bradenton, Florida)
Miami (Florida)
Mobile (Alabama)
Montevideo (Uruguay)
Montreal (Quebec)
New Orleans (Louisiana)
New York & New Jersey
Oakland (California)
Palm Beach (Florida)
Point Lisas (Trinidad and Tobago)
Portland (Oregon)
Port Everglades (Fort Lauderdale)
Richmond (Virginia)
Río Grande (Brasil)
Salina Cruz (Mexico)
San Diego (California)
San Francisco (California)
Savannah (Georgia)
Seattle (Washington)
St. John (New Brunswick)
St. John's (Newfoundland)
St. Thomas (Virgin Islands)
Stockton (California)
Tacoma (Washington)
Tampico (Mexico)
Vancouver (British Columbia)
Valparaiso (Chile)
Veracruz (Mexico)
Wilmington (Delaware)
Wilmington (North Carolina)

Port container activity and demographic and economic data on hinterland markets was additionally compiled for the following ports:

Acajutla (El Salvador)
Altamira (Mexico)
Anchorage (Alaska)
Antofagasta (Chile)
Bahia las Minas (Panama)
Barbados (Bridgetown)
Belem (Brasil)
Buenaventura (Colombia)
Callao (Peru)
Castries (St. Lucia)
Chester (Pennsylvania)
Coco Solo (Panama)
Dutch Harbor (Alaska)
Fernandina (Florida)
Fort-de-France (Martinique)
Freeport (Bahamas)
Freeport (Texas)
Hamilton (Bermuda)
Hilo (Hawaii)
Ilheus (Brasil)
Itajai (Brasil)
Kahului (Hawaii)
Kaunakakai (Hawaii)
Kawaihae (Hawaii)
Kingston (Jamaica)
Limon (Costa Rica)
Longview (Washington)
Mazatlan (Mexico)
Nassau (Bahamas)
Nawiliwili (Hawaii)
Oranjestad (Aruba)
Philadelphia (Pennsylvania)
Plymouth (Montserrat)
Pointe-a-Pitre (Guadeloupe)
Ponce (Puerto Rico)
Port au Prince (Haiti)
Port of Spain (Trinidad & Tobago)
Puerto Cabello (Venezuela)
Puerto Cortes (Honduras)
Rio Haina (Dominican Republic)
Roseau (Dominica)
San Antonio (Chile)
San Juan (Puerto Rico)
Santos (Brasil)
St. John's (Antigua & Barbuda)
Suape (Brasil)
Tampa (Florida)
Toronto (Ontario)
Tuxpan (Mexico)
Willemstad (Curaçao)

PARTICIPATING CARRIERS:

The following ocean liner companies provided data regarding some of their ports of call in the Western Hemisphere.

American President Lines, Inc.
Grancolombiana, Inc.
NYK Lines, NA, Inc.
Sea-Land Service, Inc.

William Cowart
Center for Transportation Studies
Massachusetts Institute of Technology, Room 1-133
77 Massachusetts Avenue
Cambridge, MA 02139
E-mail: wacowart@mit.edu

July 7, 1995

Dear:

The enclosed questionnaire is being distributed to container ports throughout North and South America to collect data on land-side access to seaports for academic research at M.I.T.'s Center for Transportation Studies. Completing this short questionnaire should take only a few minutes. The questionnaire was developed, in part, based on the results of the American Association of Port Authorities 1991 survey of its United States member ports, and the related 1993 report "Landside Access to U.S. Ports" prepared by the Transportation Research Board for the U.S. Maritime Administration.

In particular, this research should extend previous studies by developing a consistent, broad-based set of measures of land-side access for container traffic. The collected data will be analyzed using statistical methodologies in an effort to isolate the effects of land-side access from institutional and competitive factors. Results will therefore be useful to decision-makers in providing a generalizable quantitative measure of the specific benefits of rail, highway, and terminal access improvements.

Your cooperation in this effort, including a prompt response by fax or the enclosed envelope, would be greatly appreciated. Individual responses will, of course, be treated as confidential. In addition to your current port, please feel free to photocopy the questionnaire and complete it for any other port(s) with which you feel sufficiently familiar. Of course, please contact me at the above address, phone, fax, or e-mail if you would like any further clarification regarding this questionnaire.

Sincerely,

William A. Cowart

I would like a copy of the summary data results ________
I would like a copy of the final report's executive summary ________
Name of individual completing questionnaire ____________________
Position or title of individual ____________________
Address ____________________
____
____
____
Fax ____________________
Phone ____________________

Port: ______________________

I. CONTAINER TRAFFIC

Loaded **containers handled**, 1994

(a) including transshipped containers: _____ thousand teu

(b) excluding transshipped containers (if available): _____ thousand teu

II. CONTAINER TRANSPORT

(a) Most containers transported between the port and customers within ____ miles of the port will be transported **by truck.**

(b) Most containers transported between the port and customers more than ____ miles from the port will be transported **by rail.**

(c) **Percentage** of containers transported to / from port by:

(if drayage to/from railyards is less than 30 minutes, consider the move to be "rail only")

____ truck only ____ rail only ____ truck & rail ____ other _____ unknown

III. PORT COMPETITION

(a) **Local market share**

____ % of the ocean-going containers transported to/from destinations within the **port's metropolitan area** (within 20 miles) will utilize the port

____ % of the ocean-going containers transported to/from destinations within the **port's local region** (within 200 miles) will be served by the port

(b) **Land transport distance**

____ % of the containers using the port are transported to/from **within 20 miles**

____ % of the containers using the port are transported to/from **20 to 200 miles**

____ % of the containers using the port are transported to/from **200 to 1000 miles**

____ % of the containers using the port are transported to/from **more than 1000 miles**

IV. LAND-SIDE ACCESS

(a) **Truck**

(i) Circle the **congestion level** typically encountered in port's metropolitan area:

1 - Extreme - Containers almost always delayed by traffic, much worse than comparable nearby cities

2 - Significant - Containers usually delayed by traffic, somewhat worse than comparable nearby cities

3 - Average - Containers frequently delayed by urban traffic, similar to comparable nearby cities

4 - Little - Containers sometimes delayed by traffic, typically less than in comparable nearby cities

5 - Very little - Containers rarely delayed by urban traffic, much less than comparable nearby cities

(ii) Average **time from terminal gates** to closest major, intercity highway:

_____ hours, _____ minutes

(iii) Circle the overall level of **regional truck access** -- relative to competing ports:

1 - Excellent: Rapid, direct routes gives the port a noticeable competitive advantage to many cities within 500 miles

2 - Good: Regional highway access gives the port some competitive advantage to several cities within 500 miles

3 - Average: Regional access comparable to competing ports

4 - Below average: Poor regional highway access hurts the port's competitiveness in many cities within 500 miles

5 - Poor: Poor highway access to virtually all cities outside the metropolitan area

(b) **Rail:**

(i) Average **drayage time** from terminal gate to most commonly used rail container terminal

_____ hours, _____ minutes

(ii) Number of frequently used **container rail terminals**: ______ terminals

(iii) Circle best description of availability of **double-stack rail service**:

1 - Full on-dock/near-dock: Double **high -cube** service provided at least three times weekly from railyard(s) within 15 minutes dray of the docks

2 - Good: Double **high-cube** stack service provided at least two times weekly from railyard(s) within 60 minutes dray of the docks

3 - Available: Double stack service provided at least weekly from railyard(s) within 2 hours dray of the docks

4 - Limited: Some form of double stack service provided at occasionally from railyard(s) within 2 hours dray of the docks

5 - Unavailable: No double stack service provided except in extremely limited circumstances

(iv) Circle best description of **overall rail access** relative to other ports competing for markets more than 500 miles distant:

1 - Excellent: Better or equal access compared to all competing ports

2 - Good: Better or equal access compared to most competing ports

3 - Average: Rail access comparable to typical competing ports

4 - Below average: Somewhat worse rail access than many/most competing ports

5 - Poor: Poor rail access to distant markets

(c) **Terminal**:

(i) **Average time** for container movement from ship **to exit terminal gates**

_____ days, _____ hours

(ii) **Average time** for container movement from terminal gates **to loading on ship**

_____ days, _____ hours

(iii) Average **total port and handling charges** (lift, wharfage, handling, storage, etc.)

_____ $US (total combined 1994 charges, **per teu**)

APPENDIX C

SELECTED ADDITIONAL MODEL ESTIMATION RESULTS

Model results first are presented for specifications of the model involving only the demographic and economic characteristics of the hinterlands. The entire 99 port data set is available for analysis with these variables, and theoretically should provide a more accurate and statistically sound model. However, in some cases the smaller data set also has the model estimated, so that accurate comparisons can be made with later specifications that include the explicit access performance variables. All explanatory variables statistically significant at an 90% level of confidence or higher are highlighted in bold for ease of analysis.

Model 1:

********* ORDINARY LEAST SQUARES ESTIMATION *********

Dependent Variable: teu

Independent Variable	Estimated Coefficient	Standard Error	t-Statistic
one	7.17733e+004	2.88799e+004	2.48524
metpop	6.33966e-002	7.08349e-003	8.94992

Number of Observations	99
R-squared	0.45229
Corrected R-squared	0.44664

Model 2:

********* ORDINARY LEAST SQUARES ESTIMATION *********

Dependent Variable: teu

Independent Variable	Estimated Coefficient	Standard Error	t-Statistic
one	1.26268e+005	2.80060e+004	4.50859
metpopsq	3.77685e-009	4.68203e-010	8.06670

Number of Observations	99
R-squared	0.40150
Corrected R-squared	0.39533

Model 3:

********* ORDINARY LEAST SQUARES ESTIMATION *********

Dependent Variable: teu

Independent Variable	Estimated Coefficient	Standard Error	t-Statistic
one	7.62946e+004	2.49386e+004	3.05929
metgrp	3.58108	0.31703	11.29559

Number of Observations	99
R-squared	0.56810
Corrected R-squared	0.56365

Model 4:

********* ORDINARY LEAST SQUARES ESTIMATION *********

Dependent Variable: teu

Independent Variable	Estimated Coefficient	Standard Error	t-Statistic
one	8.19450e+004	3.02500e+004	2.70893
locgrp	2.99597	0.37739	7.93859

Number of Observations	99
R-squared	0.39383
Corrected R-squared	0.38758

Model 5:

********* ORDINARY LEAST SQUARES ESTIMATION *********

Dependent Variable: teu

Independent Variable	Estimated Coefficient	Standard Error	t-Statistic
one	6.70087e+004	4.14320e+004	1.61732
railgrp	0.10949	2.40724e-002	4.54850

Number of Observations	99
R-squared	0.17579
Corrected R-squared	0.16730

Model 6:

********* ORDINARY LEAST SQUARES ESTIMATION *********

Dependent Variable: teu

Independent Variable	Estimated Coefficient	Standard Error	t-Statistic
one	1.38275e+005	4.01022e+004	3.44807
trkgrp	0.17762	7.53861e-002	2.35619

Number of Observations	99
R-squared	5.41351e-002
Corrected R-squared	4.43839e-002

Model 7:

********* ORDINARY LEAST SQUARES ESTIMATION *********

Dependent Variable: teu

Independent Variable	Estimated Coefficient	Standard Error	t-Statistic
one	5.05417e+004	3.34788e+004	1.50966
locgrp	3.09084	0.42299	7.30709
trkgrp	-0.28323	8.35288e-002	-3.39080
railgrp	9.77690e-002	2.74941e-002	3.55600

Number of Observations	99
R-squared	0.47695
Corrected R-squared	0.46043

Model 8:

********* ORDINARY LEAST SQUARES ESTIMATION *********

Dependent Variable: lteu

Independent Variable	Estimated Coefficient	Standard Error	t-Statistic
one	4.80240	1.05154	4.56703
lmpop	0.47017	8.19985e-002	5.73390

Number of Observations	99
R-squared	0.25314
Corrected R-squared	0.24544

********* ORDINARY LEAST SQUARES ESTIMATION *********

Dependent Variable: lteu

Independent Variable	Estimated Coefficient	Standard Error	t-Statistic
one	4.04126	1.49372	2.70550
lmpop	0.55990	0.10907	5.13326

Number of Observations	49
R-squared	0.35924
Corrected R-squared	0.34561

Model 9:

********* ORDINARY LEAST SQUARES ESTIMATION *********

Dependent Variable: lteu

Independent Variable	Estimated Coefficient	Standard Error	t-Statistic
one	5.49490	1.50502	3.65105
lmgrp	0.10793	0.16733	0.64501
lmpopsq	0.17440	0.10268	1.69836

Number of Observations	99
R-squared	0.25637
Corrected R-squared	0.24087

Model 10:

********* ORDINARY LEAST SQUARES ESTIMATION *********

Dependent Variable: teu

Independent Variable	Estimated Coefficient	Standard Error	t-Statistic
one	5.03487e+004	1.28846e+004	3.90767
big	3.72155e+005	3.30823e+004	11.24939
bmetgrp	3.19756	0.20043	15.95389

Number of Observations	99
R-squared	0.89296
Corrected R-squared	0.89073

********* ORDINARY LEAST SQUARES ESTIMATION *********

Dependent Variable: teu

Independent Variable	Estimated Coefficient	Standard Error	t-Statistic
one	6.49774e+004	2.58208e+004	2.51648
big	3.38807e+005	4.78660e+004	7.07824
bmetgrp	3.27781	0.25269	12.97143

Number of Observations	49
R-squared	0.89983
Corrected R-squared	0.89547

Model 11:

********* ORDINARY LEAST SQUARES ESTIMATION *********

Dependent Variable: teu

Independent Variable	Estimated Coefficient	Standard Error	t-Statistic
one	2.54289e+004	1.65062e+004	1.54057
big	3.59932e+005	3.31976e+004	10.84211
bmetgrp	3.06752	0.19346	15.85623
inland	-5.82815e+004	4.02556e+004	-1.44779
west	8.41916e+004	2.85981e+004	2.94395
uscan	3.63315e+004	2.47520e+004	1.46782

Number of Observations	99
R-squared	0.90670
Corrected R-squared	0.90168

********* ORDINARY LEAST SQUARES ESTIMATION *********

Dependent Variable: teu

Independent Variable	Estimated Coefficient	Standard Error	t-Statistic
one	1.50022e+004	3.56483e+004	0.42084
big	3.35230e+005	4.66514e+004	7.18585
bmetgrp	3.09757	0.23474	13.19591
inland	-6.83370e+004	6.39618e+004	-1.06840
west	1.31467e+005	4.36000e+004	3.01531
uscan	4.20974e+004	4.53261e+004	0.92877

Number of Observations	49
R-squared	0.92293
Corrected R-squared	0.91396

Model 12:

********* ORDINARY LEAST SQUARES ESTIMATION *********

Dependent Variable: teu

Independent Variable	Estimated Coefficient	Standard Error	t-Statistic
one	1.74693e+004	2.01088e+003	8.68741
metpopsq	4.79521e-010	3.48095e-010	1.37756

Number of Observations	50
R-squared	3.80312e-002
Corrected R-squared	1.79902e-002

Model 13:

********* ORDINARY LEAST SQUARES ESTIMATION *********

Dependent Variable: teu

Independent Variable	Estimated Coefficient	Standard Error	t-Statistic
one	1.83899e+005	4.65391e+004	3.95149
metgrp	3.33801	0.42772	7.80415

Number of Observations	49
R-squared	0.56443
Corrected R-squared	0.55516

Model 14:

********* ORDINARY LEAST SQUARES ESTIMATION *********

Dependent Variable: teu

Independent Variable	Estimated Coefficient	Standard Error	t-Statistic
one	2.03725e+005	5.32291e+004	3.82732
metpopsq	1.83959e-009	7.60075e-010	2.42027
locgrp	1.81519	0.64317	2.82224

Number of Observations	49
R-squared	0.45716
Corrected R-squared	0.43356

Model 15:

********* ORDINARY LEAST SQUARES ESTIMATION *********

Dependent Variable: teu

Independent Variable	Estimated Coefficient	Standard Error	t-Statistic
metgrp	1.70524	0.66865	2.55029
metpopsq	1.65456e-009	7.06221e-010	2.34284
inland	-1.58536e+005	1.30252e+005	-1.21714
west	1.79100e+005	8.72674e+004	2.05231
uscan	2.85717e+005	6.51403e+004	4.38618

Number of Observations	49
R-squared	0.65956
Corrected R-squared	0.62861

Model 16:

********* ORDINARY LEAST SQUARES ESTIMATION *********

Dependent Variable: teu

Independent Variable	Estimated Coefficient	Standard Error	t-Statistic
metpopsq	4.79076e-009	5.59330e-010	8.56517
west	1.83441e+005	7.84274e+004	2.33899
uscan	2.26472e+005	4.84917e+004	4.67031

Number of Observations	49
R-squared	0.69711
Corrected R-squared	0.68394

Model 17:

********* ORDINARY LEAST SQUARES ESTIMATION *********

Dependent Variable: teu

Independent Variable	Estimated Coefficient	Standard Error	t-Statistic
one	1.50022e+004	3.56483e+004	0.42084
big	3.35230e+005	4.66514e+004	7.18585
bmetgrp	3.09757	0.23474	13.19591
inland	-6.83370e+004	6.39618e+004	-1.06840
west	1.31467e+005	4.36000e+004	3.01531
uscan	4.20974e+004	4.53261e+004	0.92877

Number of Observations	49
R-squared	0.92293
Corrected R-squared	0.91396

Model 18:

********* ORDINARY LEAST SQUARES ESTIMATION *********

Dependent Variable: teu

Independent Variable	Estimated Coefficient	Standard Error	t-Statistic
one	1.78081e+005	5.17339e+004	3.44226
metpopsq	5.23439e-009	6.36028e-010	8.22981
trk12g	5.23531e-002	8.55251e-002	0.61214

Number of Observations	49
R-squared	0.59561
Corrected R-squared	0.57803

Model 19:

********* ORDINARY LEAST SQUARES ESTIMATION *********

Dependent Variable: teu

Independent Variable	Estimated Coefficient	Standard Error	t-Statistic
one	1.18902e+005	4.63883e+004	2.56319
metgrp	3.63624	0.41768	8.70590
con12	5.73883e+004	1.11804e+005	0.51330

Number of Observations	49
R-squared	0.62997
Corrected R-squared	0.61388

Model 20:

********* ORDINARY LEAST SQUARES ESTIMATION *********

Dependent Variable: teu

Independent Variable	Estimated Coefficient	Standard Error	t-Statistic
metgrp	3.38488	0.40296	8.40014
con12	1.96433e+005	1.01675e+005	1.93197
con3	2.84723e+005	7.54779e+004	3.77227
con45	5.38819e+004	4.97959e+004	1.08206

Number of Observations	49
R-squared	0.68121
Corrected R-squared	0.65996

Model 21:

********* ORDINARY LEAST SQUARES ESTIMATION *********

Dependent Variable: teu

Independent Variable	Estimated Coefficient	Standard Error	t-Statistic
metgrp	3.07652	0.44307	6.94358
terms	9.08077e+004	2.26735e+004	4.00501

Number of Observations	49
R-squared	0.67453
Corrected R-squared	0.66760

Model 22:

********* ORDINARY LEAST SQUARES ESTIMATION *********

Dependent Variable: teu

Independent Variable	Estimated Coefficient	Standard Error	t-Statistic
metgrp	3.33543	0.38315	8.70538
rail1	3.01659e+005	7.36346e+004	4.09671
rail23	1.44166e+005	5.98951e+004	2.40698

Number of Observations	49
R-squared	0.70117
Corrected R-squared	0.68818

Model 23:

********* ORDINARY LEAST SQUARES ESTIMATION *********

Dependent Variable: teu

Independent Variable	Estimated Coefficient	Standard Error	t-Statistic
one	7.51233e+004	5.73777e+004	1.30928
metgrp	3.26268	0.39548	8.24989
ds1g	8.91597e-002	3.45853e-002	2.57797
ds2g	8.41842e-002	3.90260e-002	2.15713
ds3g	-6.51871e-002	6.14319e-002	-1.06113
ds4g	9.10347e-003	5.56371e-002	0.16362
ds5g	-7.01077e-002	4.31751e-002	-1.62380

Number of Observations	49
R-squared	0.75333
Corrected R-squared	0.71809

Model 24:

********* ORDINARY LEAST SQUARES ESTIMATION *********

Dependent Variable: teu

Independent Variable	Estimated Coefficient	Standard Error	t-Statistic
metgrp	3.21993	0.36974	8.70862
ds[illegible]	3.09329e+005	6.05409e+004	5.10941

Number of Observations	49
R-squared	0.71934
Corrected R-squared	0.71337

Model 25:

********* ORDINARY LEAST SQUARES ESTIMATION *********

Dependent Variable: teu

Independent Variable	Estimated Coefficient	Standard Error	t-Statistic
metpop	3.86491e-002	1.94031e-002	1.99190
metgrp	1.54739	0.87582	1.76678
rail1	1.31130e+004	1.04650e+005	0.12530
ds12g	0.11098	3.35551e-002	3.30752

Number of Observations	49
R-squared	0.75219
Corrected R-squared	0.73567

Model 26:

********* ORDINARY LEAST SQUARES ESTIMATION *********

Dependent Variable: teu

Independent Variable	Estimated Coefficient	Standard Error	t-Statistic
metpop	3.86571e-002	1.93953e-002	1.99312
metgrp	1.57327	0.87831	1.79124
uscan	-1.33317e+004	6.15461e+004	-0.21661
ds12g	0.11834	2.89853e-002	4.08289

Number of Observations	49
R-squared	0.75237
Corrected R-squared	0.73586

APPENDIX D

Specification of Interactive Variables:

Data transformations for testing of polynomial specifications:
METPOPSQ = METPOP * METPOP
METGRPSQ = METGRP * METGRP
TRKGRPSQ = TRKGRP * TRKGRP

Data transformations for testing of log-linear specifications:
LOGTEU = LOG(TEU)
LOGMPOP = LOG(METPOP)
LOGMGRP = LOG(METGRP)

Data transformations to attempt to reduce multicollinearity in the explanatory variables:
LOCBGRP = LOCGRP - METGRP
TRKBGRP = TRKGRP - METGRP

Interactive variables used to represent the metropolitan population near the port that is accessible at level of congestion *n*:
CON2X = CON2 * METPOP
CON3X = CON3 * METPOP
CON4X = CON4 * METPOP
CON5X = CON5 * METPOP
CON34X = CON3X + CON4X

Interactive variables used to represent the hinterland GRP served at regional level of truck access *n*:
TRK1X = TRK1 * TRKGRP
TRK2X = TRK2 * TRKGRP
TRK345X = TRK345 * TRKGRP
TRK12X = TRK1X + TRK2X

Data transformations to reduce multicollinearity in the explanatory interactive variables used to represent the hinterland GRP served at regional level of truck access *n*:
TRKB1X = TRK1 * TRKBGRP
TRKB2X = TRK2 * TRKBGRP

TRKB345X = TRK345 * TRKBGRP
TRKB12X = TRKB1X + TRKB2X

Interactive variables used to represent the hinterland GRP served at regional level of rail access *n*:
RAIL1X = RAIL1 * RAILGRP
RAIL2X = RAIL2 * RAILGRP
RAIL3X = RAIL3 * RAILGRP
RAIL4X = RAIL4 * RAILGRP
RAIL12X = RAIL1X + RAIL2X
RAIL34X = RAIL3X + RAIL4X

Data transformations used to represent ports providing double-stack service at any of the specified levels:
DS12 = DS1 + DS2
DS123 = DS1 + DS2 + DS3

Interactive variables used to represent the hinterland GRP where double-stack rail service is available at level *n*:
DS1X = DS1 * RAILGRP
DS2X = DS2 * RAILGRP
DS3X = DS3 * RAILGRP
DS4X = DS4 * RAILGRP
DS12X = DS1X + DS2X
DS123X = DS1X + DS2X + DS3X

Interactive variables used to test specifications in which there are potential structural differences between the U.S. and other countries in the landside access / seaport activity relationship:
SMETPOP = USA * METPOP
SMETGRP = USA * METGRP
SRAILGRP = USA * RAILGRP
SINLAND = USA * INLAND
SONE = USA * ONE
SRAIL1X = USA * RAIL1X
SRAIL2X = USA * RAIL2X
SRAIL12X = USA * RAIL12X
SRAIL34X = USA * RAIL34X

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