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Several Approaches to Estimating Low-Valued Exports from the U.S.

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Several Approaches to Estimating Low-Valued Exports from the U.S.

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Abstract

Each month the U. S. Census Bureau receives from the Customs and Border Protection Service documents describing all U.S. exports over $2,500. Most exporters now file the required documents via the Automated Export System. Because of filing options, for the majority of exporters, we have no information on "low-valued" exports (LVEs), those valued at or below the exemption level of $2,500; for the remainder, we have records for all LVEs. As exporters are not required to report their LVEs, the Census Bureau estimates the low-valued component for any country by multiplying its total of exports valued over $2,500 by a pre-determined factor. This factor, specific to the country of export, was determined in the late 1980's based on data collected up to that point in time. However, while export patterns--commodities, modes of transport, quantities, and values--have changed, the factors remain the same. Some experts believe that the current system may underestimate LVEs.

In this paper, we look back at research into several approaches to estimate LVEs. The goal was to develop robust procedures that accurately represent what is currently being exported, and can adapt over time with minimal review to reflect changes in export patterns. After reviewing background on the collection of export data and the estimation of LVEs, we briefly describe several methods for estimating LVEs. In all of these strategies, we start by combining exports into groups determined by common features, such as the export's commodity or its mode of transport. We review methods based on (1) data from the small portion of exporters who report their LVEs, (2) export data to Canada and from courier shippers, (3) models that try to predict how an exporter will file, and (4) models that hypothesize that some shippers split their exports into smaller pieces to avoid filing export documents. The research reveals promising aspects of the approaches as well as serious flaws.

Key words: exemption level, international trade, reconciliation study, Customs, courier.

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Several Approaches to Estimating Low-Valued Exports from the U.S.

1. Introduction

Each month the U. S. Census Bureau receives from the Customs and Border Protection Service (Customs) documents describing all U.S. exports over $2,500. In an attempt to keep the burden of filing low, exporters are not required to report their "low-valued" exports (LVEs), those valued at or under $2,500. To assist exporters in complying with Customs regulations, most exporters now file the required documents via the Automated Export System. They have two choices: they can summarize all their shipment data valued over $2,500 by commodity number; or they can report each transaction or invoice, above or below $2,500, as an individual commodity line item. This leaves us with two groups of filers: summary, for whom we do not have information on exports below the exemption level of $2,500; and invoice, for whom we have records for all LVEs (perhaps with some underreporting).

Because exporters need not report their LVEs, the Census Bureau estimates the low-valued component for any country by multiplying its total of exports valued over $2,500 by a pre-determined factor. This factor, specific to the country of export, was determined in the late 1980's based on data collected up to that point in time. However, while export patterns--commodities, modes of transport, quantities, and values--have changed, the factors remain the same. Based on years of in-depth analysis and several reconciliation studies with other countries, some experts at the Census Bureau and the Bureau of Economic Analysis believe that the current system may underestimate LVEs.

In this paper, we look back at research into several approaches to estimate LVEs. Our original goal was to derive one or more robust estimation procedures that (1) accurately represent what is currently being exported, and (2) can adapt over time with minimal review to reflect changes in export patterns.

Part A presents background and general information on the collection and estimation of LVEs. Discussed are a recent history of estimating LVEs, the development and implementation of the Automated Export System, and evidence that LVEs may currently be underestimated. Part B briefly describes several methods for estimating LVEs. In all of these strategies, we start by combining exports into groups determined by common features, such as the export's commodity or its mode of transport. We review methods based on (1) data from invoice filers, (2) export data to Canada and from courier shippers, (3) models that try to predict how an exporter will file, and (4) models that hypothesize that some shippers split their exports into smaller pieces to avoid filing export documents. Although the research offers insight into the problem, each approach contains serious flaws--obstacles to be resolved adequately before it could be implemented in practice.

Part A. Background and General Information

2. Some History of Estimating Low-Valued Exports

The Foreign Trade Division of the U.S. Census Bureau publishes the nation's official international trade statistics, including data on imports and exports. The division began estimating LVEs in the 1960s. Starting then, to reduce processing costs and filer burden, the Bureau has set exemption levels; shippers have only been required to report complete export data for transactions valued greater than a specified exemption level. Exports valued below this level have been estimated using country-specific factors. The LVEs for each country are produced by multiplying that country's factor by its previous month's export total above the exemption level.

From 1965 to 1989 the Census Bureau revised these factors every few years, or with each change in the exemption level. The updates reflected changing trade patterns. For a given country, this process of updating factors was done by examining the change--from the prior year to the current year--in the proportion of total trade accounted for in the range from the exemption level to twice the exemption level.

In January 1985, the exemption level was raised from $500 to $1,000, and the low-value factors were adjusted as a result. For each country, the existing factor (call it f_{OLD}) was used to estimate the total value of items valued $500 or below, denoted by x_1. Then a sample of data from 1984 was used to measure the total value between $501 and $1,000, x_2, and the total value greater than $1,000, x_3. The new factor, f_{NEW}, was then determined as follows: $x_1 = f_{OLD}\,(x_2 + x_3)$ and $x_1 + x_2 = f_{NEW}\,x_3$, leading to $f_{NEW} = (x_1 + x_2) / x_3 = \{\, f_{OLD}\,(x_2 + x_3) + x_2 \,\} / x_3$.

3. Development of the Automated Export System (AES)

Since the low-valued export factors were determined in the late 1980's, the system for collecting and processing export data has evolved. The Automated Export System (AES) is now the main avenue through which export shipment data are electronically filed to the Customs and Border Protection Service (Customs). A filer can be an exporter or an authorized forwarding agent.

AES provides exporters with an alternative to filing paper Shipper's Export Declarations (SEDs). Although initiated in 1995, electronic filing on AES has been possible for all ports and for all modes of transport since 1997. The number of exporters using AES has grown steadily. As of January 2003, 85.9% of all eligible export shipments were filed on AES. While using AES is currently optional, the Security Assistance Act of 2002 allows filing via AES to be made mandatory for all shipments requiring an SED.

Filing via AES provides many advantages and options that are not available with paper SEDs. Data collected on AES can be edited immediately to ensure that filers comply with current U.S. export reporting requirements, and to identify data reporting errors. The system informs filers of these errors and allows them to make corrections. This benefits filers, but also improves the Census Bureau's export trade statistics.

Another feature of AES is providing options on how to file. Exporters can choose to file their data (1) at the summary level, where they must summarize all their shipment data valued $2501 or more by commodity number, or (2) at the invoice (detailed) level, where each transaction--regardless of value--must be reported as an individual commodity line item. Those who elect to file on an invoice basis are expected to report all their records, regardless of value. AES provides all these benefits, while simultaneously reducing costs associated with handling and keying paper documents, correcting errors, and duplicate reporting.

Table 1 provides a breakdown of all exports in a typical month from parts of 2002 and 2003, and how they were filed. One can see the dichotomy of concern to us: the invoice exports, for which LVEs are available; versus the summary exports (summary AES and paper), for which LVEs are not observed (shaded in the table). Currently, about 15% to 20% by volume of those using the AES provide invoice data, including information on their low-valued exports. Excluding Canada, around 2003, non-AES (paper) data represented about 13% of exports, and 20% of total volume of exports. This portion should decrease to 0% over time.

Table 1. Exports by Reporting Method and Size; Data from 2002 and 2003[1]

Records in a Typical Month (excluding Canada)	Automated Export System (AES) 1,170,000 records observed		Non-AES (Paper) 180,000 records observed
	Invoice (Non-Summary)	**Summary**	**Summary** (only)
High-Valued Exports: > $2,500	230,000	710,000	180,000
Low-Valued Exports: ≤ $2,500	230,000	*Not Observed*	*Not Observed*

[1] Frequencies are based on an average of three months in 2002 and 2003, and rounded to the nearest 10,000.

For more information on technological changes and other types of improvements to the reporting and filing of exports, see U.S. Census Bureau (Sept. 16, 1998).

4. Are Low-Valued Exports Underestimated?

Some experts at the Census Bureau and the Bureau of Economic Analysis conjecture that the Census Bureau's current method for tabulating export data and estimating LVEs underestimates the true value of LVEs. From an information paper posted on the Census Bureau's website, "Understatement of Export Merchandise Trade Data" (U.S. Census Bureau, July 1998), one reads the following:

> It appears that our estimates of low value trade are too low. ... Companies involved in air cargo trade tell us that our estimates significantly understate the proportion of low valued transactions in U.S. exports.
>
> We have examined the issue in our reconciliation studies and found that underestimation of low valued trade accounted for up to 3 percent of the reported value of U.S. exports to those countries. However, this estimate is very rough since trading partners can define their reporting codes differently than the United States, thus

> creating more or less low valued trade relative to the United States. We were only able to obtain this information from three trading partners--Australia, Korea and Mexico. The underestimation appears to differ significantly from country to country. So, while these comparisons support our belief that we underestimate low value trade, they do not provide a basis firm enough for correcting our estimates.

This excerpt cites reconciliation studies of exports conducted jointly by the Census Bureau and several other countries. These studies have been designed "to identify and adjust for conceptual and definitional differences [between countries] so we could investigate the remaining differences" (U.S. Census Bureau, Dec. 19, 1996). According to studies cited (ibid.), LVEs to Australia in 1993 (1994), estimated at $381 ($450) million, were underestimated by $236 ($265) million, or about 38% (37%). (For a related paper available on-line, see Australian Bureau of Statistics, Sept., 1996.)

Documentation of reconciliation studies on U.S. exports to Mexico for the years 1996 through 1999 can be found in U.S. Census Bureau (Aug. 3, 2000; Oct. 1, 2001), posted on the Census Bureau's website. Table 2 summarizes some results from the studies.

Table 2. Reconciliation of U.S. Exports to Mexico, Including LVEs, 1996 - 1997 (in millions of U.S. dollars)

	1996	1997	1998	1999
Total Mexican published imports	67,526	82,002	93,252	105,267
Total U.S. published exports	56,792	71,378	78,772	86,909
Underestimate in total	10,734	10,624	14,480	18,358
Estimate of reconciled U.S. LVEs	3,220	3,833	3,997	4,447
U.S. Published LVEs	2,079	2,613	2,884	3,182
Estimate of underestimate in LVEs	1,141	1,220	1,113	1,265
Estimated percent of LVE missed	35.4%	31.8%	27.8%	28.4%

According to the latter studies, in the late 1990's the U.S. underreported LVEs to Mexico by 27% to 36%.

Several years ago, low- and high-valued export data from March 2000 were obtained directly from several major couriers. For each, their actual value of LVEs was more than ten times higher than the number computed under the current LVE estimation procedure. Caution should be taken, however, when examining data on couriers, whose exporting tendencies cannot be considered anything like the norm.

Part B. Approaches to Estimating Low-Valued Exports

5. Grouping Exports by Key Characteristics

In applying low-value factors to the totals of high-valued exports from summary reporters within a country, we want the procedure to be robust to changes in export patterns. For example, suppose that the United States has been shipping heavily in grain and fruit to a certain country. The low- to high-value ratio (LVR) of exports for that country should reflect such an export history. But suppose that later the U.S. starts exporting computers and electronic equipment to the same country. Without a change in the LVR, the new estimate of LVEs will be based on the old export pattern, implicitly assuming that the ratio of low- to high-valued exports tends to be the same across the different commodity groups.

Rather than make such a questionable assumption, we propose that any new approach to estimating LVEs start by dividing all exports into groups *j* within countries so that the total of LVEs for country *i* can be estimated as the sum of the LVEs estimated within each group, as in equation (1):

$$\mathrm{LVE}_i = \sum_{j=1}^{G} \mathrm{LVE}_{ij} = \sum_{j=1}^{G} f_{ij}\, \mathrm{HVE}_{ij} \qquad \textbf{(1)}$$

where G is the number of groups, f_{ij} is the LVR for group j in country i, and LVE_{ij} and HVE_{ij} are the low- and high-valued exports, respectively, in group j from country i. One might well consider an approach in which f_{ij} does not depend on the country i, that is, where the same group factor is used in different countries. We suspect that the LVR should rely more on the type of export than on the country of destination.

Variables That Influence the Low-to-High-Value Ratios

To determine the composition of the groups for computing LVRs, we investigated the effects of many variables, including the mode of transport and the commodity. Mode of transport takes one of three values--vessel (over sea), air, or over-land--and is defined to be the mode used as the export leaves the United States, even though the shipment may stop in more than one country and several modes may eventually be used. For example, if a shipment is brought to Mexico by truck or rail before being sent by vessel to Costa Rica, the export's mode and destination are characterized as over-land to Costa Rica. Over-land includes all exports that are not by vessel or air. To describe types of commodities, we started with the two-digit codes or "chapters" of the Schedule B, the ten-digit hierarchical classification system used to collect and compile U.S. export statistics.

We tested the hypotheses that mode of transport and chapter level influence the LVRs of invoice data by conducting analysis of variance on the data. The first analysis modeled LVRs as a function of country, mode, and two-digit chapter code, and included all two-way interactions. We limited the data to include 28 countries and 20 two-digit chapter codes, each highly ranked

in terms of total export value. The data came from invoice reports of exports from May 2002 to July 2002; the ratios were computed for each month. We found that the LVRs depend highly on country, mode of transport, and chapter, as well as on all the two-way combinations.

We repeated many of the studies on data collected in October through December of 2002 to see how consistent the observed relationships are over time. In addition, we concatenated the data sets, attaching to each record an indicator of the time period, May-July or October-December. After repeating the earlier analyses, we tested for a difference in the LVRs from one time period to the next. Although country, mode of transport, and chapter (as well as their two-way interactions) showed significant effects on the values of the LVRs, the difference over time was not statistically significant, lending support to the notion that the observed relationships are consistent over time.

How many groups should be used? With more groups, finer distinctions can be made within the set of exports, whether they be divided by commodity types or other characteristics. On the other hand, as the groups become small in number of shipments or total volume of exports, there are fewer data on which to base the LVR used to estimate the group's LVE, possibly leading to decreased stability in the estimate.

6. Investigating Reported Invoice Data

Our early research into the problem is summarized in this section. For greater detail on the methods, analyses, and results, see Cantwell, Fescina, and McCullough (2003). The focus of this investigation was the data obtained from invoice filers. These exporters file on an individual basis for every export regardless of value. Thus, their true total of LVEs can be tabulated. There were several motives to this work. We wanted to

- develop new factors for estimating LVEs based on groups defined on commodity and mode of transport, use them to estimate the actual LVEs for invoice filers, and compare the result to the current procedure, which is based on the country factor;

- examine whether dividing all exports into finer groups made this estimation more accurate; and

- observe what kind of estimated *summary* LVEs would result from applying the low-valued ratios (LVRs) based on invoice data.

For the last point, it was of interest to ask whether invoice filers are similar to summary filers in terms of the exports that we can see, specifically, those in the lower ranges of values. Table 3 provides summary statistics--the two quartiles, the median, and the mean--of exports from October through December, 2002, in several ranges according to the method of filing.

Table 3. Summary of Exports in Selected Ranges, October to December, 2002

	Range of Value of Exports				
	$0 - $2,500	$2,501 - $5,000	$2,501 - $10,000	$2,501 - $20,000	> $2,501
			AES Invoice		
Q1	55	2,965	3,364	3,696	4,162
Median	185	3,509	4,579	5,611	7,562
Mean	397	3,594	5,080	7,231	32,360
Q3	522	4,189	6,470	9,664	18,223
			AES Summary		
Q1	*Not*	3,000	3,598	4,268	5,800
Median	*Available*	3,575	5,060	7,157	12,990
Mean		3,641	5,489	8,422	59,154
Q3		4,242	7,198	11,827	32,731
			Paper		
Q1	*Not*	3,000	3,500	3,968	4,772
Median	*Available*	3,550	4,849	6,300	9,669
Mean		3,637	5,308	7,787	46,584
Q3		4,224	6,885	10,654	23,829

Except for the first column of LVEs, the ranges are bounded below by $2,501, and above by $5,000, $10,000, $20,000, or ∞ (that is, no limit). Results using an upper bound of $15,000 were analogous, and are omitted to save space. From Table 3, one sees that, as the interval's upper bound increases, the summary statistics are less alike across the three methods of filing. However, the statistics are very similar across the methods within the interval ($2,500, $5,000]. This result implies that, when addressing missing data for summary files based on invoice (observed) data, one might want to restrict the procedure to data in a range that does not greatly exceed $2,500.

We started by developing LVR factors from the data of invoice filers based on the exports' country of destination, the mode of transport, and the commodity. This analysis ignored all exports to Canada. More will be said about exports to Canada in Section 7.

In our analysis, we addressed the issue of sparse data within the newly proposed export groups. Because export traffic to many countries is heavy enough within all or most groups, there are ample data to compute group LVRs. But for many other countries and at least some export groups, the data are sparse enough to raise concern about the stability of the data from that country on which the estimated LVR is made. In an attempt to stabilize the resulting LVR, where fewer data are available from country *i*, information was drawn from elsewhere in the same "block" of countries as country *i*. We defined a composite factor for combining data:

$$c_{ij} = \lambda_{ij} f_{ij} + (1 - \lambda_{ij}) f_{ij}' \qquad \textbf{(2)}$$

where $0 \le \lambda_{ij} \le 1$, f_{ij} is the LVR for group *j* in country *i*, and f_{ij}' is the LVR for group *j* based on the remaining countries in the block containing country *i*. There are various ways one could combine countries into blocks for the purpose of borrowing strength, such as combining countries whose LVRs are most alike within the groups. For reasons described in Cantwell, Fescina, and McCullough (2003), we formed blocks from countries that are geographically proximate, that is, generally on the same continent or part of the continent.

Note that the composite factor combines exports with data on exports *in the same group* (commodity × mode of transport) from other geographically nearby countries. The premise is that the LVR depends more on the type of export--for example, the type of commodity or method to ship it--than on the country of destination.

Results and Observations

To evaluate the proposed procedures, we extracted data from the Automated Export System for the months May 2002 through April 2003. Twelve months were used in an attempt to minimize seasonal effects on the analysis. We retained all exports from invoice filers, and removed all exports from summary filers. By restricting the analysis to invoice-level exports, we had access to all LVEs; we could derive estimates and compare them to the actual total of the LVEs.

The data were divided into four subsets of equal size, with each record having the same chance of falling into any of the four subsets. The idea was to determine LVRs from one subset, apply them to the other three subsets, and compute the absolute relative error in estimating the total of invoice LVEs. Using all four subsets to determine LVRs and three subsets each time to evaluate the procedures, we obtained 12 quasi-independent applications. The strategy allowed us to get an idea of the accuracy and the variability of the procedures.

We focused on six countries in Europe: three "large" countries, those to which we export a high volume of goods, the United Kingdom, Germany, and France; and three "smaller" countries, Denmark, Portugal, and Greece. The estimators were also studied as applied to other countries--large and small, inside and outside Europe--often with similar results.

It should be noted that the exercise here was to estimate the total of *invoice* LVEs based on the available invoice high-valued exports, with the hope that some result might point to a viable procedure for estimating *summary* LVEs. Because the total of summary LVEs is unknown, this was not part of the evaluation (although we make some comments below). Further, the Foreign Trade Division's task is not necessarily to estimate separately the invoice and summary LVEs, but only their sum. Following are some of the results of the analyses.

- Applying LVRs within groups based on commodity and mode of transport appears to be beneficial to the estimation.

- Allowing a composite factor as in (2) improved the technique's performance sharply for the "large" countries, and to a lesser extent for the smaller countries.

- Taking a proportion of the higher-valued exports from the range ($2,500, $10,000] provided better LVEs than taking a proportion from the range ($2,500, *Z*], where *Z* is $5,000, $20,000, or ∞. For the current procedure, $Z = \infty$ is used.

- For the most part, the proposed alternatives estimated the true total of invoice LVEs with small absolute relative error. The current procedure based only on the country code vastly overestimated the true total for the invoice component of LVEs.

The last result must be put into proper context. It is possible that the current country factors, developed in the late 1980's based on export patterns at the time, (a) no longer reflect well the current patterns of LVEs, or (b) perhaps estimate well the total of LVEs *across invoice and summary exports*. Regardless, if we believe the reconciliation studies that imply an underestimate in total LVEs (see Section 4), the conclusion must be that the current procedure vastly underestimates the summary component of LVEs.

7. Data from Canada and Couriers

Exports to Canada

The Canadian Government requires that documents be filed on all imports to Canada, regardless of value. Therefore, Canada collects data on all U.S. exports to Canada, including those below the exemption level of $2,500 filed via summary or invoice. As a result of a data agreement between the U.S. and Canada, the Foreign Trade Division does not compute totals for exports from the U.S. to Canada, but relies on the Canadian import statistics from the U.S. In our research, we sought ways to use these Canadian data to help estimate LVEs for the rest of the world within groups to be specified.

We started by defining export groups in some way, perhaps by commodity or mode of transport, etc. The question is whether, for example, electronic equipment shipped by air from the U.S. to Canada might be similar to electronic equipment shipped by air from the U.S. to Belgium or Ecuador, at least in terms of the low-value ratio (LVR). If one believes that such a comparison can be made within export group, one might use the data available from U.S. exports to Canada to help develop LVRs within groups.

There were several initial issues that raised concerns.

- Are there sufficient data on exports to Canada to provide estimates of LVRs for various groups? For some commodity groups, the U.S. exports little or nothing to Canada, perhaps because Canada produces that commodity or because Canada imports that commodity from countries other than the U.S. Yet the U.S. may well export that commodity to other countries. The extent of this problem would depend on how many such gaps exist among the groups as defined.

- Does Canada's physical location adjacent to the U.S. render it sufficiently different from most other countries? A much greater proportion of our exports to Canada travel by over-land than to other countries (except Mexico). Similarly, the proportion of our exports to Canada by vessel (over sea) is unlike that to other countries. Perhaps a relationship could be made for groups defined by commodity × air.

- While Canadian import data include all U.S. exports to Canada valued above and below $2,500 (adjustments for the different currencies can be applied), no distinction is made on whether that export was filed via summary or invoice. That is, we cannot separate the LVR for exports to Canada into its components for summary and invoice filers.

We continue, without resolving these issues. Within any group *g*, we can denote the LVR for *all* exports from the U.S. to Canada as LVR_g^{CANADA}; the LVR for *all* exports to the rest of the world by $LVR_g^{WORLD,\ TOTAL}$; and the LVR for summary and invoice exports to the rest of the world by $LVR_g^{WORLD,\ SUMMARY}$ and $LVR_g^{WORLD,\ INVOICE}$, respectively. Note that we can estimate LVR_g^{CANADA} and $LVR_g^{WORLD,\ INVOICE}$ for any specified period of time from the available data. One would like to relate $LVR_g^{WORLD,\ SUMMARY}$ to its Canadian analogue for summary data as well. But, as noted in the third bullet above, we cannot break LVR_g^{CANADA} into its components.

We tried to estimate the unknown $LVR_g^{WORLD,\ TOTAL}$ for group *g* by a linear combination of the known ratios:

$$\lambda_g\, LVR_g^{CANADA} + (1 - \lambda_g)\, LVR_g^{WORLD,\ INVOICE} \qquad \textbf{(3)}$$

where $0 \le \lambda_g \le 1$. A value of λ_g close to 1 signifies a strong reliance on (a) the relationship between the LVRs to Canada and to the rest of the world, at least within group *g*, and (b) the fact that the LVR to Canada is known, that is, is obtained from actual data. The question of how to select λ_g, that is, how much weight to place on the Canadian LVR, was secondary. More important, was making a reasonable argument that each of the two LVRs in equation (3) are legitimate proxies for the unknown $LVR_g^{WORLD,\ TOTAL}$.

Although the use of the second term in (3) could introduce a downward bias in our estimate, it might be worthwhile to stabilize the estimate. However, based on our prior research that tried to extend the use of LVRs computed from exports filed via invoice (see Section 6), we had a difficult time justifying the use of $LVR_g^{WORLD,\ INVOICE}$ in (3), unless the value of $1-\lambda_g$ was quite small. Our initial hope lay more with the term LVR_g^{CANADA}.

We conducted various analyses of export data for groups defined as two-digit chapters--a breakdown by commodity groups (see Section 5)--crossed with the air mode of transport. Unfortunately, our investigation left us with little confidence that the any type of consistent relationship between the Canadian air LVR and the world's LVR for invoice exports is strong enough to support valid estimation of LVR for all air exports, including summary, to the world.

We investigated other more complex approaches that took advantage of the observed data from

Canadian imports, but without success. With the other issues mentioned above also unresolved, we could not find a defendable way to use Canadian import data to help estimate U.S. LVEs.

Data from Couriers

More recently, the Foreign Trade Division decided to explore more thoroughly the exports of couriers. The bulk of the courier business in the U.S. is concentrated in a small number of companies. Members of the division contacted one of the major couriers that generally reports its exports via summary, and asked if they would provide a data file with all their exports over a period of months. The company complied, giving us records of exports that contained, among other fields, the value of the shipment. The data recorded exports from July 2004 through July 2005.

With some reluctance, we tried to determine a method whereby the data from this summary exporter, containing exports valued above and below the exemption level, might be used for general low-valued estimation. Finding a way to generalize the unusual circumstances of a courier was difficult. Due to the nature of the business, a courier often ships goods under constraints of time or weight, both of which can affect the value and type of commodity to be exported. Further, the concentration of the courier business in a small set of companies is atypical of many other industries.

It was no surprise that we could not generalize quantitative results from the courier business to others. But we discussed ways to apply LVRs based on the observed courier data to high-valued totals *within the courier trade*. Using fields available on all export records, one can separate all exports shipped by courier and treat them as a distinct group. Worth mentioning is that our analyses of courier data from the one company assisted us in one of our later approaches, as discussed in Section 9.

8. Modeling the Probability of Filing via Summary or Invoice

As another approach to estimating LVEs, we tried to model the probabilities that an export selected at random from all exports would be filed via the summary (or invoice) procedure. The plan was to let the best model fit help us estimate the volume in the low-valued range, from $0 to $2,500, from summary filers.

Modeling Approach

We started by considering only exports with value ≤ $10,000, and breaking this range into four smaller ranges: ($0, $2,500], ($2,500, $5,000], ($5,000, $7,500], and ($7,500, $10,000]. Other ranges and divisions could be considered. From available data within country or group (e.g., by commodity or mode of transport), we planned to tally the frequency of exports within the four ranges. In each range, the exports could then be divided into those shipped by filers who use the summary method and those who use the invoice method, creating eight frequency cells. The frequencies in seven cells can be tabulated. We would not have the data for one cell: the low-

valued exports (LVEs) from summary filers. This number would be estimated from the model.

We then postulated a probability model for the likelihood that a given export was filed by the summary--rather than invoice--method, conditional on the (average) value of the export in the given range:

$$p_s = p_s(x, \theta) = \Pr\{ \text{export filed by summary} \mid x, \theta \} \quad \textbf{(4)}$$

where x is the (average) value of the export, and θ represents a set of unknown parameters.

The objective then was to determine the frequency or volume of summary LVEs that would yield the best model fit for all eight cells. We suspect that many exporters select a reporting method--summary or invoice--according to factors that do not depend on the size of the export, and whether or not it falls below the exemption level of $2,500. However, it is possible that a subset of exporters hope to avoid filing export documents, and consequently file via summary if they have a large number of relatively small exports. If so, the population of exporters may be a mixture of the two types. With the possibility of this mixture, one might want p_s to be a decreasing function of x. Similarly, based on results discussed in Section 6, we believe that exports shipped by summary filers make up a disproportionately larger share of the LVE range. Thus, we selected probability models whereby p_s decreases as the export value increases. Under this scenario, for small x, p_s would be larger; as x grows larger, p_s would decrease.

Under the model, we determine estimates for the total number of exports in the range, ($0, $10,000], and any parameters represented by θ. This might be a maximum likelihood or other type of estimator. With these estimates, we determine the modeled sum of the LVEs reported by summary. This number can be added to the sum of the LVEs reported by invoice to obtain an estimate of total LVEs.

To evaluate the model, we compare what is predicted by the model to what we observe in the export data. For example, we might determine the sum of exports in observable ranges, such as ($0, $2,500], ($2,500, $5,000], ($5,000, $7,500], and ($7,500, $10,000] for invoice; for summary, the same intervals except for ($0, $2,500]. Within the specified ranges, the sums predicted by the model can be compared to the analogous observed sums, with some measure of the differences computed.

Results of Modeling

We tried several models for $p_s(x, \theta) = \Pr\{ \text{export filed by summary} \mid x, \theta \}$, each satisfying the restriction that p_s be a decreasing function of x. Two simple models were $p_s(x, \theta) = \exp(-mx)$, with $m > 0$; and $p_s(x, \theta) = 1 - b_0 - b_1 x$, with b_0 and b_1 each > 0.

Unfortunately, the approach did not work; we should have looked at the data before concentrating on the models. We extracted the exports to several important trading partners of the U.S.--Mexico, China, and the United Kingdom--for the period February through July, 2006,

and tabulated the frequencies and values over the ranges given above, ($0, $2,500], ($2,500, $5,000], ($5,000, $7,500], and ($7,500, $10,000]. But as the value of the shipments over these ranges increases above the exemption level of $2,500, that is, as we move from the second to the third to the fourth range, the observed proportion of summary exports as measured by frequency or value *increases*, contrary to our expectations.

Obviously, regardless of the specific model or parameter(s) selected, a model for $p_s(x, \theta)$ that decreases with increasing x will yield a poor fit to these data. Another option is to fit a model in which $p_s(x, \theta)$ increases with x. The problem with this model is that it would provide an estimate of summary LVEs below that derived using the invoice LVR applied to the higher-valued exports. Such an estimate would fit the data much better, but would be inconsistent with our beliefs about the underestimate of LVEs, as discussed in Section 4. However, a different assumption about the filing behavior of exporters might explain the observed data and lead to larger estimates of summary LVEs. That assumption is considered in the next section.

9. Applying the Hypothesis that Many Filers Split Their Exports

We considered an alternative that might explain the observed pattern of data in the range ($0, $10,000]. Is it possible that a subset of filers who have a large number of exports with values slightly above the exemption level are interpreting the filing requirements to where they would not have to file for some exports? Could they be "splitting their exports" into smaller ones whose value is below the exemption level? For example, a book dealer ships an order of textbooks to one location in another country. The order contains 4 cartons of texts, with 10 texts in each carton, and each text valued at $100. Taken as one export, the shipment is worth 4 × 10 × $100, or $4,000, and an export document must be filed with Customs. But the dealer can consider each carton as a separate export, each worth $1,000, which is below the exemption level. If he or she files by summary, he need not report the exports.

Do we believe that all filers are thinking this way? No. Many, perhaps most, exporters may choose to report via summary or invoice for other reasons, depending perhaps on their electronic filing or accounting system, on which method they consider cheaper or more efficient, or even on the method they have grown accustomed to. However, if all exporters made their decision based on factors independent of the value of their exports, we would expect that the proportion of summary exports out of all exports reported, $p_s(x, \theta)$, would be similar from one interval to the next above $2,500, that is, across the intervals ($2,500, $5,000), ($5,000, $7,500), ($7,500, $10,000), etc. This is not the case.

If a nontrivial portion of filers "split their exports," at least for relatively low values, we would expect to observe differing proportions of summary exports. In fact, we might expect to see the proportion of summary documents observed decrease as the export values decrease towards the exemption level. For those who split exports at times, they may be more likely to do this for "splittable" exports whose values are closer to the exemption level. The mixture of all exporters--those who report according to one method regardless of the export's value, and those who split exports for intermediate values--could produce the conjectured result.

To check the conjecture, we analyzed all exports--except those to Canada--from a six-month period, February through July, 2006. The exports were placed by value in ranges of width $2,500, and the proportion of summary exports out of all exports computed for each range, as in Table 4. This was done for the world total of exports, for the breakdown of exports by section number (commodity grouping), and for all countries; results for three countries are shown.

Table 4. Proportions of Summary Exports Out of All Exports (Frequency, Value) Within Ranges of Values. Data from the Automated Export System, February to July, 2006

	Range of Export Values in Interval[1]			
	$2,500 - $5,000	$5,000 - $7,500	$7,500 - $10,000	$10,000 or more
World Total	69.3%, 69.3%	72.0%, 72.1%	73.8%, 73.8%	79.2%, 85.0%
By Commodity Section[2] Number				
1	79.7%, 79.7%	84.2%, 84.4%	89.6%, 89.6%	92.8%, 91.2%
2	63.0%, 63.3%	67.4%, 67.6%	71.5%, 71.6%	78.6%, 87.4%
3	76.4%, 76.2%	78.5%, 78.6%	82.0%, 82.0%	89.0%, 94.2%
4	72.1%, 72.4%	77.7%, 77.8%	87.2%, 87.3%	91.6%, 95.1%
5	69.3%, 69.5%	73.2%, 73.4%	79.7%, 79.8%	87.3%, 90.4%
6	67.0%, 67.1%	69.2%, 69.3%	66.8%, 66.8%	75.2%, 78.8%
7	69.3%, 68.4%	68.6%, 68.5%	69.2%, 69.0%	59.1%, 76.9%
8	77.8%, 78.0%	79.4%, 79.5%	81.2%, 81.3%	86.2%, 88.4%
By Selected Countries				
Mexico	38.8%, 39.0%	46.4%, 46.7%	52.2%, 52.3%	64.8%, 65.9%
China	73.9%, 74.2%	73.0%, 73.1%	77.0%, 77.3%	81.3%, 83.1%
United Kingdom	85.2%, 85.3%	86.0%, 86.0%	87.1%, 87.1%	87.6%, 91.3%

[1] Summary exports are not required to be filed if they are below the exemption level of $2,500.
[2] Section refers to a classification of exports by commodity type.

Over all exports for the period, the proportion of summary exports does indeed increase as the range of values increases. This pattern is repeated for most of the section breakouts as well, although not for commodity Section 7.

We also analyzed the data on all exports, above and below the exemption level, provided by a major courier, described in the Section 7 of this paper. Exports with values between $0 and $5,000 were assigned to smaller intervals of width $250 to better evaluate the distribution of values. The data for the first available month, July 2004, are shown in Table 5. Other months reveal a similar pattern.

Table 5. Frequencies of Exports from a Major Courier by Value Within Ranges, July 2004

Exports With Values *Below* the Exemption Level			Exports With Values *Above* the Exemption Level		
Range of Values	Frequency	Percent	Range of Values	Frequency	Percent
$0 - $250	780,280	69.66%	$2,500 - $2,750	4,852	0.43%
$250 - $500	105,384	9.41%	$2,750 - $3,000	5,449	0.49%
$500 - $750	53,560	4.78%	$3,000 - $3,250	3,845	0.34%
$750 - $1,000	40,910	3.65%	$3,250 - $3,500	3,813	0.34%
$1,000 - $1,250	25,809	2.30%	$3,500 - $3,750	3,372	0.30%
$1,250 - $1,500	21,854	1.95%	$3,750 - $4,000	3,452	0.31%
$1,500 - $1,750	16,173	1.44%	$4,000 - $4,250	2,659	0.24%
$1,750 - $2,000	16,627	1.48%	$4,250 - $4,500	2,708	0.24%
$2,000 - $2,250	11,540	1.03%	$4,500 - $4,750	2,150	0.19%
$2,250 - $2,500	12,847	1.15%	$4,750 - $5,000	2,808	0.25%

Due to the nature of the courier business, it is not surprising to see the majority of the exports in the first interval, values below $250. The frequencies then stabilize somewhat with a downward trend over succeeding intervals, up to $2,500. But there is a substantial drop in the frequencies from the intervals with values less than $2,500 to those with values greater than $2,500. Thereafter, the frequencies again are stable, slightly decreasing with increasing export values in general.

In addition to the tendency for this courier to ship goods whose value is small, there is no question that something is going on that produces many more exports just below the exemption level than above it. We have no proof of our hypothesis that some exporters may be splitting their shipments to avoid filing Customs documents. However, these data are consistent with such an hypothesis.

Current Approach Briefly in Words

Another strategy for estimating LVEs then is based on the conjecture--not proven--that a subset of summary exporters are splitting some of their exports, especially those with values closer to the exemption level, to avoid filing documents with Customs. For example, in the interval from $2,500 to $5,000, we observe the summary exports that were not split. But we hypothesize that the remaining summary exports in this interval were split into values below $2,500 and that no documents were filed on them. The result is that some portion of summary exports that could have fallen in the $2,500 to $5,000 range end up as unreported summary LVEs. For exports in the interval of $5,000 to $7,500, a similar pattern of splitting the exports may occur, but to a

lesser extent.

This implies that the unreported summary LVEs contains two components: (1) those summary exports whose values would have been below the exemption level to begin, and (2) those summary exports whose values originally were above the exemption level, but were split into pieces with values below the exemption level.

How do we estimate the value of such exports, which are never recorded on paper? Our approach is based on the "threshold assumption" that, for exports of value above some threshold, for example, $10,000, there is little or no tendency for filers to split exports. Thus, of exports above the threshold, the proportion filed via summary, $p_s(x, \Theta)$, does not depend on x. Further, it is an estimate of the proportion of all exports that would have been filed via summary had there been no exemption for filing below the exemption level of $2,500.

Applying this assumption, we deduce that, within intervals between the exemption level and the threshold, one can estimate the true value (before splitting) of summary exports by increasing the level of summary exports in the interval until its proportion of all exports in the interval is p_s. The difference between this hypothesized level and the observed level is an estimate of what was split and ended up as unobserved summary LVEs. If the same procedure is applied to all intervals below the threshold, one can sum and obtain an estimate of the total summary LVEs.

Current Approach in Statistical Terms

Let c represent the exemption level, $2,500, below which exporters need not file documents with the Customs and Border Protection Service. Following the strategy described above, let P_s be the true but unknown proportion of exports that would be filed via summary if there were no exemption for exports below c. We assume there is some threshold, denoted by t ($> c$), and an interval, $(t, w]$, in which the proportion of exports filed by summary is indeed equal to P_s on average over time.

For example, the values t and w might be taken as $10,000 and $15,000, respectively. Alternatively, w can be taken as ∞. For w, we hesitate to use a value too much larger than t, because we will estimate P_s based on the interval $(t, w]$. As the value of w increases substantially, we feel less secure basing the estimation of summary low-valued exports on a relationship involving exports of such large value. Further, we wish to prevent undue influence from possible atypically large values of exports, values that might be considered outliers or influential values in some sense.

We break the interval $(c, t]$ into m intervals of arbitrary length for some positive integer m. If we include the intervals $(0, c]$, $(t, w]$, and (w, ∞), the positive real line is split into $m+3$ ordered intervals representing the possible values of all exports. (For what follows, if $w = \infty$, the final interval is empty, and there are effectively only $m+2$ intervals.) For $i = 1, 2, \ldots, m+3$, let x_i be the sum of the values of all invoice exports whose value falls in interval i. Similarly, let y_i be the analogous sum for summary exports that are reported. Only exports valued below w are

considered in the estimation. Note that y_1 is not known and will not be used in the estimation.

We estimate P_s using all exports in the $(m+2)$nd interval, $(t, w]$, above the threshold:

$$p_s = \frac{y_{m+2}}{x_{m+2} + y_{m+2}} \quad \textbf{(5)}$$

(Aside: Instead of basing p_s on the *total values* of summary and invoice exports in the interval $(t, w]$, we could base it on the *number* of exports in the interval. Often, there will be little difference; see Table 4. It is easily seen that a single export of value v can often be reported as two (or more) exports having values v_1 and v_2, where $v_1 + v_2 = v$; see example, page 14. Because, under alternative reporting options the number of exports can change, while the total value remains the same, we prefer to work with the total value of exports, rather than the number.)

Next, for $i = 1, 2, \ldots, m+1$, we estimate the true value of summary exports that would originally have fallen in interval i, denoted by z_i, under the hypothesis that summary exporters are splitting their shipments as described above. For this, we assume that the proportion of summary exports based on the hypothesized value z_i remains constant across intervals at the estimated value, p_s. It follows that

$$p_s = \frac{z_i}{x_i + z_i} \quad \textbf{(6)}$$

or equivalently from equation (5), that

$$z_i = x_i \cdot \frac{p_s}{1 - p_s} = x_i \cdot \frac{y_{m+2}}{x_{m+2}} \quad \textbf{(7)}$$

The value z_1 estimates only the first component (see above) of summary LVEs. The second component is estimated by the sum of the residuals of z_i above the value of the observed y_i,

$$z_i - y_i = x_i \frac{y_{m+2}}{x_{m+2}} - y_i \quad \textbf{(8)}$$

over $i = 2, 3, \ldots, m+1$. Thus, we estimate the summary LVEs as

$$\widehat{\mathrm{LVE}}^{\,\mathrm{SUMMARY}} = x_1 \frac{y_{m+2}}{x_{m+2}} + \sum_{i=2}^{m+1} \left[x_i \frac{y_{m+2}}{x_{m+2}} - y_i \right]$$

$$= \frac{y_{m+2}}{x_{m+2}} \left(\sum_{i=1}^{m+1} x_i \right) - \left(\sum_{i=2}^{m+1} y_i \right) \quad \textbf{(9)}$$

Adding the observed invoice LVEs, x_1, the estimate for all LVEs is

$$\widehat{\mathrm{LVE}}^{\,\mathrm{TOTAL}} = x_1 + \frac{y_{m+2}}{x_{m+2}} \left(\sum_{i=1}^{m+1} x_i \right) - \left(\sum_{i=2}^{m+1} y_i \right) \quad \textbf{(10)}$$

Aside: It has been suggested that even the volume of observed invoice LVEs suffers from undercoverage, that some invoice filers may not be reporting all their LVEs. If there is evidence or reason to believe that only some fraction, φ, $0 < \varphi < 1$, of invoice LVEs are reported, one can

replace x_1 in the derivation above by x_1/φ to account for the suspected undercoverage. It is unlikely that this adjustment will affect the estimate substantially.

Application to Recent Data

To see the approach more clearly, it is applied to recent exports to Mexico. Table 6 summarizes the results.

Table 6. Reported and Hypothesized Exports to Mexico (in $Millions) with (*t, w*] = ($10,000, ∞). Data from the Automated Export System, February to July, 2006

Range	Reported Invoice	Reported Summary	Hypothesized Summary	Hypothesized "Split" into Summary LVE
$0 - $2,500	958.385	-----	***1,853.963***	
$2,500 - $5,000	2,451.284	1,569.228	*4,741.923*	***3,172.695***
$5,000 - $7,500	1,833.709	1,605.927	*3,547.247*	***1,941.320***
$7,500 - $10,000	1,409.905	1,547.626	*2,727.412*	***1,179.786***
> $10,000	26,766.374	51,778.618	51,778.618	
Total	33,419.657	56,501.399	64,649.163	6,293.801

For this example with $w = \infty$ for simplicity, we compute the ratio of exports where there is no tendency to split summary exports based on the range greater than $10,000: 51,778.618 / 26,766.374 = 1.9345. Under the hypothesis that a subset of summary filers are splitting their exports under $10,000, the hypothesized total of summary exports--had they not split their exports--is projected in the fourth column in italics.

What we cannot observe are the exports that have been split into LVEs to avoid the filing requirements; the projected amounts are computed by deduction and found in the final column. Adding the hypothesized totals that may have ended up as unobserved summary LVEs, seen in bold in the table, produces $8,147.764 million. If one adds the reported invoice LVEs, the estimate of total LVEs is $9,106.149 million. This compares with an estimate of $3,380.581 million under the current procedure.

From the derivations in this section, one may notice two things. First, to simply compute the estimate of summary or total LVEs, there is no need to divide the interval (c, t] into subintervals; see equations (9) and (10). We did this to motivate the hypothesis that some exporters may be splitting their exports, and to demonstrate how the observed value of $p_s(x, \theta)$ can actually increase as the value of the export, x, increases over the range (c, t].

Second and more important, when estimating the total value of *all* exports, the approach described here ignores the reported value of summary exports within the interval (c, t]. To see

this, one can add the observed value of the high-valued exports, those greater that *c*, to the estimate of total LVEs:

$$\widehat{\text{Export}}^{\text{TOTAL}} = \widehat{\text{LVE}}^{\text{TOTAL}} + \sum_{i=2}^{m+1} x_i + \sum_{i=2}^{m+1} y_i + x_{m+2} + y_{m+2} + x_{m+3} + y_{m+3}$$

$$= x_1 + \frac{y_{m+2}}{x_{m+2}} \left(\sum_{i=1}^{m+1} x_i \right) - \left(\sum_{i=2}^{m+1} y_i \right) + \left(\sum_{i=2}^{m+1} x_i \right) + \left(\sum_{i=2}^{m+1} y_i \right) + x_{m+2} + y_{m+2} + x_{m+3} + y_{m+3}$$

$$= \left(1 + \frac{y_{m+2}}{x_{m+2}} \right) \left(\sum_{i=1}^{m+2} x_i \right) + x_{m+3} + y_{m+3} \qquad \textbf{(11)}$$

As one combines the estimated second component of summary LVEs, that is, the residuals $z_i - y_i$ from equation (4), with the observed values y_i over the intervals $i = 2, 3, \ldots, m+1$, the y_i's are replaced by $(y_{m+1}/x_{m+1}) x_i$. The question remains: In estimating the total of all exports, should one apply a technique that ignores this small observed component of the total data, in order to perhaps obtain a better estimate for another unobserved component?

In table 7, we summarize some results of the analyses as applied to the world total, to the breakdown of exports by section number (commodity grouping), and to three countries, again for the months of February through July, 2006. Each table entry is the estimate of total LVEs--invoice and summary--for the domain and the method specified. We thought it would be more appropriate to estimate the total of all LVEs, rather than just the summary LVEs, as that is what the current procedure does.

The current method applies a country factor or LVR to all exports. As the sections cover exports going to many countries throughout the world, we derived a composite country factor for the world, .0287, by weighting the current country factors by their proportion of the total exports above the exemption level during these six months. We then applied the composite country factor in lieu of deriving composite factors within each section. Obviously, the proper composite factors would differ somewhat from .0287, so the numbers in the second column below (Current Method) may be poor proxies in some cases.

The numbers in the third column (Based on the Invoice Ratio) apply the LVRs as derived from the invoice exports only. As we discussed in Sections 4 and 6, it appears that applying this LVR to estimate the total of all LVEs may produce a serious underestimate. These numbers are provided for reference only.

For each of Mexico and China, the proposed hypothesized approach produces an estimate of total LVEs that is about 2.7 times that under the current method. However, this ratio is only about .64 for the United Kingdom. For the world total of LVEs, the ratio is about 2.1. The results for the sections are less reliable because we used the composite country factor for the world, rather than for the individual sections. However, one might suppose that the proposed

approach produces estimates of LVEs that are larger than under the current method within most sections.

Table 7. Estimated Total Low-Valued Exports (LVEs) (in $Millions), Invoice and Summary, by Several Methods. Data from the Automated Export System, February to July, 2006

	Current Method	Based on the Invoice Ratio	Proposed Hypothesized Approach
World Total	9,361.827	3,387.305	19,632.019
By Commodity Section[1, 2] Number			
1	971.800	347.641	1,388.808
2	1,763.251	926.065	5,451.068
3	332.592	204.704	1,808.433
4	753.917	273.481	1,793.732
5	433.567	659.154	2,994.603
6	3,238.338	1,026.005	4,978.137
7	852.425	69.320	722.218
8	1,016.052	274.868	1,831.881
By Selected Countries			
Mexico	3,380.581	2,626.530	9,106.149
China	181.718	71.325	486.711
United Kingdom	1,391.658	149.883	894.142

[1] For Sections, the composite country factor from the World Total was used.
[2] Section refers to a classification of exports by commodity type.

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