VERTICAL TRADE AND EXPORT PROCESSING OF ESTABLISHMENTS: MEASUREMENT MATTERS

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Vertical Trade and Export Processing of Establishments: Measurement Matters

Abstract Fragmentation of production processes has generated two-way or vertical trade in intermediate goods including for export processing. The literature on measuring the extent of this vertical specialization trade involves measurement procedures within an input-output framework. In this paper, utilizing a geometric framework of the production box, we propose to measure vertical trade (*VT*) as the overlap of exports and imports at the establishment level where imports represent an assortment of imported inputs. A high degree of overlap between exports (X) and imported inputs ($Minp$) denotes processing trade. *VT* can be aggregated for all establishments and computed at the industry level. Normalization of *VT* on gross output (Q) is introduced as VTQ and normalization of *VT* on total trade using ISIC production data is a *VTindex* akin to the Grubel-Lloyd index. We frame the VTQ measure, the *VTindex* and other selected trade specialization measures in the production box of establishments. The VTQ measure is a function of the commonly used offshoring index, $Minp/Q$, in the net-export plane and the export-intensity index, *X/Q*, in the net-import plane and thus, in its measurement incorporates both the *VS* share of exports and *VS* share of imports respectively as in Hummels et al. (2001).

Keywords Vertical trade, Vertical specialization trade, export processing trade

JEL Classification F10, F14, F23

1 Introduction

In the trade and development literature, export-oriented industrialization has generally been well received. But export-processing industrialization also yields high export-output ratios. Export-processing industrialization arises from the splicing of the production chain resulting in trade of intermediate goods—spatial disintegration of production processes across countries/regions. Traditionally, in an era of limited mobility of factors of production; a single country produces goods from start to finish or produce complete value chains and then trade these goods. Thus, exports or the ability to penetrate another country's market signify competitiveness of the exporting country in the production of the particular commodity resulting in the positive connotation of exports with industrialization. Imports of goods from abroad (also produced from start to finish abroad) compete with similar goods produced domestically, yielding the term import-substitutes for the latter country. Trade barriers thus promote the local producer by making imports more expensive.

In an era of liberalization of commodity and factor trade across countries with technological advancement leading to decreasing transportation costs (Markusen 1998) and increasing imports of intermediate inputs in production processes (offshoring) coupled with foreign direct investment (FDI) relocating parts of the production chain to take advantage of unequal factor prices across countries; ownership of production does not necessarily reside in the hands of residents of a country (Greenaway et al. 2001). In this current context of segmentation of the production chain with segments exhibiting different factor proportion requirements and by drawing on different factor markets for different fragments across countries *ala* Heckscher Ohlin type of specialization (Kohler, 2004); the concept of export-oriented industrialization is increasingly unclear.

Increasing exports attributed to increasing imports of intermediate goods as a result of mid-stream processing cannot be equated with export-oriented industrialization in the traditional context of production of complete value chains. Similarly, the learning by exporting hypothesis literature presupposes that production from start to finish of a good is geographically fixed and that ownership of establishments resides with the residents of the exporting country. Using exporter status as a dummy to investigate differences between establishments that export and do not export automatically includes export processing establishments in the export group. Parents of foreign affiliates and their subsidiaries may be entwined in a web of production networks across countries and strategize on modes of foreign entry and exporting with respect to third country markets without the attendant effects of exporting *per se* on productivity. Moreover, developing countries in their quest for industrialization may legislate that a large portion of output should be exported as a pre-condition for allowing foreign direct investment into the developing host country. Thus, there is a need to ascertain the extent of overlapping vertical trade or two-way trade with higher degrees of involvement in two-way trade denoted as export-processing trade especially by foreign-owned establishments in the presence of global production networks.[1]

The *Annual Survey of Manufacturing Industries* (ASMI) for establishments in countries like Malaysia and others do not capture whether the imported inputs and ensuing exports are for processing purposes or otherwise pointing to the need to construct indices that capture the intensity of two-way or vertical trade at the establishment level.[2] This paper has three major contributions: first, it highlights that where the variable import is concerned, Standard International Trade Classification (SITC) data and ASMI data based on International Standard Industrial Classification (ISIC) are two different "entities". Second, this study constructs a new

[1] Empirical studies on processing trade of China (Xing 2012; Fu 2011) recognize that conventional trade patterns have been reversed with the proliferation of foreign invested enterprises such that China export high-tech products while industrialized countries like the US import high-tech goods. Earlier on, Markusen (1998) modeled the phenomena of the reversal of trade flows within the context of decreasing trade costs (including transportation costs) and FDI liberalization in the global economy. Baldone et al. (2007) refers to an "inversion" in revealed comparative advantage with fragmentation of production.

[2] In the case of China, Yu (2010) manage to link at the establishment level, customs data and production data from the annual survey of manufacturing enterprises via a common identification number of establishments in both data sets. The customs data is very rich including a breakdown of many specific types of processing trade. Merging of data sets from these two sources may not be possible for other countries in order to address the issue of export processing trade. For details on the special regulatory arrangements for processing trade in China, see Fernandes and Tang (2012).

measure of vertical trade introduced in a geometric framework at the establishment level exploiting ASMI data, which is the highest level of disaggregation possible based on currently available databases.[3] A high degree of vertical trade relative to production shows export processing trade. Third, other trade related indices are framed in the establishment production box.

The remainder of the paper proceeds as follows. Section 2 highlights the differences between SITC data and Annual Surveys of Manufacturing Industries based on ISIC data used in the measurement of trade related issues and reviews related literature that uses these two data sets. Section 3 introduces the measurement of overlapping vertical trade with the establishment as the point of reference using the production box of establishments. Some selected trade specialization measures are framed in the establishment production box in Section 4. Concluding comments are provided in Section 5.

2 Review of related literature that "overlooks" and "notices" processing trade

In the international trade literature, one common measure of revealed comparative advantage (RCA) in a particular industry in a country is the net export to total trade ratio ($(X - M)/(X + M)$) as shown in Ballance et al. (1987). When using SITC data, both exports and imports denote trading in a particular commodity at the 3-digit level (or other more disaggregated level). Trade data is collected mainly by border control agencies such as the Customs Department of a particular country and imports as well as exports refer to a particular SITC category.

Net exports of industries in ASMI based on ISIC data aggregated from establishment level data does not carry the same meaning as net exports in SITC data simply because imports in ASMI refer to an assortment of imported inputs from all industries abroad whereas imports in the latter classification refer to the same commodity classification as exports. Imports in ISIC production data refer to an assortment of imported inputs used in the production of the particular ISIC product and thus is a mapping of "many" different imported inputs

[3] Baldwin (2006) describes the "first unbundling" of globalisation with the firm considered as the lowest level of aggregation to be analyzed. The "second unbundling" of globalisation began with the relocation of different parts of production in different locations and "tasks" considered as the lowest level of disaggregation and not firms.

into “one” classification of ISIC based on output (and exports).[4] The current literature on trade and productivity use ISIC data that focus on production and not on consumption. At the establishment level; exports denote the exports (output) of the establishment according to the ISIC category that the establishment belong to. But imports at the establishment level denote an assortment of imported inputs from all industries abroad not necessarily belonging to the same ISIC category as output and exports.[5] Aggregation from the establishment level data to product categories in ISIC is applicable to export data but aggregation of an assortment of imported inputs from all industries abroad at the establishment level results in an assortment of imported inputs not necessarily all belonging to the same ISIC category as exports.

In the literature on exports and productivity (ISGEP 2008); it is assumed that exports are produced from scratch and that learning occurs from exporting and thus spills over to productivity improvements at the plant level or vice-versa where productivity of establishments improve prior to exporting in order to overcome sunk costs of exporting of previously non-exporting establishments. But higher volume of exports can arise mainly from processing of higher volumes of imported inputs and not from exporting *per se*. The unbundling of exports as a result of vertical trade and exporting *per se* is necessary when examining the exports and productivity literature in the presence of significant export processing trade or “fragmentability” of value chains (Srholec, 2007).[6] Baldone et al. (2007) also alluded to this phenomena of vertical trade and suggest that RCA (revealed comparative advantage) indices built on total trade flows should be distinguished from trade flows leaving aside inward processing and outward processing trade.

Higher volume of exports does not necessarily signify the success of export-oriented industrialization. The effects of exports on productivity without disentangling processing of imported inputs for exports point to the need for proper accounting of the role of imported inputs for further processing in studies examining the role of exports in promoting productivity of establishments. Furthermore, mainly subsidiaries of foreign firms may be involved in the export-processing activities and subsequently trade, and not domestic firms which further “complicate” all of the above. Production of final goods using imported inputs (foreign outsourcing/offshoring)

[4] Ballance et al (1987, p.158) states: “The major disadvantage with trade-cum-production indices is that trade data and production data are generally collected using different industrial classifications.”

[5] It should be stressed here that net-exports of establishments that is based on surveys of manufacturing industries does not carry the same meaning as net exports based on SITC data. In the former, exports represent output but the imported inputs of establishments can be from many different categories. For example, an establishment produces toy dolls, but the imports are rubberized plastic, cloth, ”fake” hair, etc. and these inputs does not compete with output of the establishment. Imports at the establishment level can also refer to machinery used for production, a capital good which renders capital services and is a component of value added.

[6] In the ISGEP (2008, p. 604) study, “China was considered an outlier with the highest level of export intensity across exporting firms”. We suspect that processing trade contributed to this result.

and assembling of imported inputs mainly for exporting (processing trade) needs to be distinguished in studies on productivity and exporting. Customs statistics can be used to provide a narrow measure of international fragmentation in production such as the US Offshore Assembly Programme (Swenson 2005) and the European Union Processing Trade data sets (Baldone et al. 2005). The work of Ng and Yeats (1999) use SITC data to measure fragmentation based on trade in parts and components relative to total trade. The accessibility of SITC data and comparability across countries and specific trading partners is the main advantage of this data. But the drawback of this SITC data include the difficulty to demarcate the use of imported inputs for "normal" or "ordinary" production of establishments as opposed to vertical or fragmented trade and to link to other establishment and industrial level characteristics such as gross output and foreign ownership, thus not permitting disentanglement of arms' length versus transactions within firms.

The majority of the evidence on international fragmentation measures vertical specialization as the imported input shares of gross output, total intermediate inputs or exports (Amador and Cabral 2009). Backward linkages within an economy are identified when the imported input content of total intermediate inputs used in production is low. At the industry level, measures of vertical specialization (VS) follow the tradition of Hummels et al. (2001) using input-output (I-O) tables for the different broad industries taking into account both exports and imported inputs relative to gross output in their VS index. Geishecker and Görg (2005) measure fragmentation for a particular industry as the ratio of imported inputs from all industries abroad relative to the industry output without considering exports of the industry. Amador and Cabral (2009) construct a VS index based on a three-step methodology which is a relative measure, suitable for cross-country studies. In step one, ISIC trade data at the 4-digit level is combined with IO tables; the latter used to identify the main imported intermediate inputs *i* used in the production of good *j*. In the second step, VS activities are identified when export share of product *j* and imported input share of product *i* simultaneously exceed the threshold given by the respective world average shares. In the third step, quantification of VS trade is computed as the value of intermediate imported inputs *i* that surpass the threshold in the second step which accounts for exports.

The significance of vertical specialization based trade as alluded to by Hummels et al. (1998, 2001) is captured using production data. Hummels et al. (1998, p. 81) measure the amount of imported inputs as a fraction of gross output embodied in a country's exports multiplied by "two" as vertical specialization based trade. Specifically, vertical specialization (VS) based trade is defined as follows:

Vertical specialization trade = fraction of gross production that is imported intermediates $*$ exports $*$ 2

= imported intermediates $*$ fraction of gross production that is exported $*$ 2

$$= 2 * X * \frac{Minp}{Q} \tag{1}$$

where X denotes exports, $Minp$ denotes imported inputs and Q denotes gross output. This vertical specialization measure is weighted by Q.

Hummels et al. (2001, p. 78) redefines vertical specialization share of exports akin to equation (1) above but removes the number "two". Thus, for country k and good or sector i, vertical specialization trade is defined as follows:

$$VS_{ki} = \frac{imported\ intermediates}{gross\ output}.exports \tag{2}$$

Data from input-output tables for 10 countries were compared in Hummels et al. (2001) in order to measure the extent of embodiment of imported inputs in the exported output. We are interested in measuring vertical trade at the establishment level and thus, review the adaptation of the Hummels et al. (2001) index to establishment level data.

Tucci (2005) adopts the framework of Hummels et al. (2001) but applies it to establishment level data in an attempt to measure trade related to production networks. Tucci (2005) observe that the measure of Hummels et al. (2001) does not have an upper bound while the lower bound is zero when either exports or imports of establishments is zero.[7] Tucci (2005) then introduces a firm level normalization of the Hummels et al. (2001) index by dividing by the total materials input used in production resulting in an index bounded by zero and one with the upper bound attained when all inputs are imported and all output are sold abroad. Tucci (2005) also suggests a more direct manner of measuring involvement in foreign networks by using the import content of exports ($Minp/Exports$). This paper constructs a relatively direct alternative measurement of vertical trade at the establishment level which is additive across establishments and industries using the production box of establishments in the following section.

[7] The Hummels et al. (2001) measure at the establishment level is actually bounded by Q since $X < Q$ and $Minp < Q$ and therefore $X * Minp < Q^2$ or $\frac{X*Minp}{Q} < Q$ or VS < Q.

3 The Establishment Production Box

Azhar et al. (1998) provide a geometric representation of trade at the product or industry level for a particular country to be used in conjunction with SITC data. Exports and imports of a particular industry are encapsulated in an industry trade box enabling the depiction of isoclines of total trade (TT), net trade (NT) and intra-industry trade (IIT). Akin to the industry trade box of Azhar et al. (1998), we introduce the production box of establishments which encompasses production of establishments framed within an input-output framework. Embedded within this production box in the south-west corner is the trade box of establishments with Cartesian coordinates $(X, Minp)$. Imports represent an assortment of imported inputs $(Minp)$ on the horizontal axis whereas exports (X) represent that part of the output not consumed locally on the vertical axis.

Based on ISIC data, we define the volume of overlapping exports and an assortment of imported inputs at the establishment level as vertical trade (VT). The equation used to measure vertical trade is shown below:

$$VT_i = 2\min(X_i\,, Minp_i) \tag{3}$$

where i indexes establishments and X_i and $Minp_i$ are respectively exports and imported inputs of establishment i. In the net export plane of establishments, $VT_i=2*Minp_i$ and in the net import plane $VT_i=2*X_i$. Thus, VT quantifies matching trade or two-way trade of an establishment and provides for the different degrees of involvement of two-way traders and not just a "dummy" for participation or non-participation in two-way trade.

VT is akin to IIT as used in the numerator of the Grubel-Lloyd index. In order to normalize this absolute measure of VT, we use the normalization as shown in Hummels et al.'s (2001) VS measure, namely gross output of establishments. Vertical trade as a share of output (VTQ) is defined as follows:

$$VTQ_i = \frac{2\min(X_i, Minp_i)}{Q_i} = \frac{2\min(X_i, Minp_i)}{Q_i} \tag{4}$$

where i indexes establishments and X_i and $Minp_i$ are respectively exports and imported inputs of establishment i and Q_i refers to gross output of the establishment. The VTQ measure take on values in the interval [0, 2) with the lower bound indicating production only with domestic intermediate inputs or sales only in the domestic market and the upper bound showing that all output is exported and all intermediate inputs are imported inputs. The VTQ measure satisfy the three conditions stipulated in Hummels et al. (2001, p.77) in order for vertical specialization (VS) to occur: first, sequential linkage in production; second, value added in the production of a good must be generated in at least two countries and third, “at least one country must use imported inputs in its stage of the production process, and some of the resulting output must be exported”. The VTQ measure can be aggregated to industry and country levels and this is a useful property for further econometric investigations of vertical trade. Aggregating over all establishments in a particular industry provides a share measure of vertical trade relative to gross output in an industry *j*.

$$VTQ_j = (\Sigma_{i\in j} VT_i)/Q_j \tag{5}$$

where *i* indexes establishments, *j* indexes industries and Q_j refers to total output of all establishments in industry *j*. *VT* can be normalized on total trade of establishments yielding a *VTindex* as follows:

$$VTindex_i = \frac{2\min(X_i, Minp_i)}{X_i + Minp_i} = \frac{2\min(X_i, Minp_i)}{X_i + Minp_i} \tag{6}$$

Aggregating vertical trade over all establishments *i* in a particular industry *j* results in a share measure of vertical trade to total trade in industry *j* akin to the Grubel-Lloyd index.

$$VTindex_j = \frac{\Sigma_{i\in j}(VT_i)}{\Sigma_{i\in j}(X_i + Minp_i)} \tag{7}$$

3.1 Vertical trade in the establishment production box

Consider the production box (square) of an establishment in a hypothetical industry as shown in Figure 1. The dimension of the square production box is denoted by gross output (Q) with the horizontal axis depicting inputs and the vertical axis showing output. Inputs for production at the establishment level comprises of imported inputs, domestic inputs and value added from services of primary factors like capital (which may be imported) and labour (which includes foreign labour). Gross output or production can either be exported or consumed locally. The trade of establishments can be embedded in the south-west corner of the production box of establishments with the dimensions of the rectangle given by exports on the vertical axis and imported inputs on the horizontal axis.[8] *VT* equals zero for trade points located on the vertical or horizontal axis. The isoclines that are parallel to the vertical axis (horizontal axis) represent equal volumes of vertical trade for net exporting (importing) establishments. For example, in the net export (NX) plane where $X > Minp$ and X falls perpendicularly (but remains above the bisector of the production box), then absolute *VT* remains constant at 2*min (X or $Minp$), i.e. 2* $Minp$. Similarly, for trade points where $X < Minp$, the trade point is mapped horizontally to the vertical or export axis to obtain *VT* as 2*X. For example, for a given trade point T_0 with co-ordinates (X_0, $Minp_0$) as shown in Figure 1, *VT* equals 2*$Minp_0$. For another trade point T_1, with co-ordinates (X_1, $Minp_1$), *VT* equals 2*X_1. We can partition the production box into a foreign and domestic region with the trade point T acting as the "pseudo-origin" for the domestic aspects of production. As point T approaches the true origin of the establishment production box, the trading activities of the establishment diminishes and the domestic component of production and consumption expands. The equi-*VT* line is the set of trade combinations that give equal absolute *VT* values as shown by the "L-shaped" lines with the vertex on the diagonal of the production box akin to a Leontief function.

<Insert **Figure 1** about here>

Consider any trade point (X, $Minp$) in the production box.[9] Let $X > Minp$ and the ratio of exports to imported inputs equal r_x, that is,

$$\frac{X}{Minp} = r_x \tag{8}$$

Akin to the traditional Grubel Lloyd index, we define a $VTindex$ where

$$VTindex = \frac{VT}{TT}$$

or $$VT = (X + Minp) - |X - Minp| = VTindex(X + Minp) \tag{9}$$

In the case $X > Minp$ so $|X - Minp| = (X - Minp)$, and from (8) substituting $X = r_x Minp$ into (9) we have:

[8] Details of the trade aspects of establishments are adapted from the trade box analysis of Azhar et al. (1988) based on SITC data.
[9] This section draws heavily from Azhar et al. (1998) adapted to establishment level trade.

$$2 * Minp = VTindex(r_x Minp + Minp)$$

i.e.
$$VTindex = \frac{2Minp}{r_x Minp + Minp} = \frac{2}{r_x + 1} \tag{10a}$$

Analogously in the case of $X < Minp$ and $r_{Minp} = Minp/X$, equation (10a) becomes

$$VTindex = \frac{2}{r_{Minp} + 1} \tag{10b}$$

For all (non-zero) trade combinations we can represent the $VTindex$ in terms of the relevant trade ratio, r_x and r_{Minp}. In the static context, the $VTindex$ is a function of the trade ratio $X/Minp$ for trade points in the net-export plane and $Minp/X$ in the net-import (NM) plane with the tangent of the angles α and β respectively in Figure 1 depicting the relevant trade ratios, r_x and r_{Minp} as in equation (10a) and equation (10b). Tucci (2005) suggest the use of the import content of exports, $Minp/X$, to measure involvement in foreign networks but the $VTindex$ introduced in this paper is also a function of $Minp/X$ ($= r_{Minp}$) albeit for net-importing establishments. Thus, the index suggested by Tucci (2005) captures vertical trade only for net-importing establishments based on the $VTindex$ introduced in this article and not under all circumstances.

The $VTindex$ is the ratio of vertical trade to total trade irrespective of the volume of trade relative to production of the establishment. For example, in Figure 1, all trade points located on the ray $0T_0$ yield an identical $VTindex$ and similarly all trade points located on the ray $0T_1$ possess a higher $VTindex$ than trade points on $0T_0$. Trade points in the neighbourhood of the origin show small amounts of trade but can yield a high $VTindex$ when the relevant trade ratio is high. In the following sub-section, we frame the *VTQ* measure which shows the proportion of vertical trade relative to gross production of the establishment and properly reflect the importance of vertical trade to the establishment unlike the $VTindex$ which reflect the proportion of vertical trade relative to total trade of the establishment.

3.2 The *VTQ* measure in the establishment production box

The total trade of establishments may be small relative to gross output; thus the use of the *VTQ* measure in equation (4) provides for the normalization of *VT* relative to total output. On the vertical axis of the establishment production box, output of an establishment is either exported or sold domestically. Similarly, on the horizontal axis, intermediate inputs are imported or sourced domestically and value added from the primary factors is added to arrive at gross production from the input side providing for an input-output framework at the establishment level. For non-trading establishments, all output is sold domestically and all inputs are sourced domestically and the establishment trade box collapses to the point of origin of the production box. Trade points located on the imported inputs axis show production with imported inputs for local markets only (not exported) whereas trade points located on the vertical axis show production for export markets without the use of imported inputs both with a VTQ measure of zero. Plotting of establishment trade points relative to gross output of establishments enable policy makers to envision simultaneously trade and production and to design appropriate policies with respect to enhancement of competitiveness. A geometric representation of the VTQ measure in a trade box with dimensions given by the gross output of the establishment considered is shown in Figure 2.

<insert **Figure 2** about here>

In the establishment production box of Figure 2, the VTQ measure is identical along the "L-shaped" lines denoted AA' and BB' since VT is identical along these lines and gross output is fixed as given by the dimensions of the production box. In the NX plane of Figure 2, trade points along the vertical section of AA' have identical VT given by 2* $Minp_0$ with VTQ = (2* $Minp_0$)/Q and along the horizontal section of AA' in the NM plane, $VTQ = 2*X_0/Q$ with the tangent of the angles γ and γ' respectively depicting half of the VTQ measure. Similarly, along BB', the VTQ measure in the NX plane and NM plane respectively is two times the tangent of the angles θ and θ' and that θ = θ'. As VT increases, the VTQ measure proportionately increases and approaches the north-east corner of the box where the VTQ measure approaches 2. In Figure 2, trade points R, S, T, U and V yield identical VTQ indices and trade points L, M and N yield identical VTQ indices with the latter points having larger VTQ indices compared to the former points. Thus, the VTQ measure is a function of $Minp/Q$ (X/Q) in the NX (NM) plane, with establishments conducting substantial amounts of VT trade situated in the north-east corner of the production box denoted as export processing trade establishments or "ultra" two-way traders.[10] It should be pointed out that studies on exporting, importing and productivity (Sjöholm 1999; ISGEP 2008) use export intensity (X/Q) and imported input intensity ($Minp/Q$) as independent variables which also denote vertical trade for net importing establishments and net exporting establishments respectively based

[10] In the case of the *VTQ* measure, the higher the volume of vertical trade, the higher the vertical trade normalized on a given Q as shown respectively by γ and θ. In Figure 1, α for trade points in the NX plane is inversely related to the *VTindex*. There does not appear to be a one to one correspondence between the *VTindex* and the *VTQ* measure. Trade points located on a given equi *VTindex* line will yield higher *VTQ* measures away from the origin. Similarly, trade points situated on a given equi *VTQ* measure can yield different *VTindex* with trade points situated on rays originating from the origin away from the bisector having a smaller *VTindex*.

on the *VTQ* measure introduced in this article. In other words, the same offshoring index ($Minp/Q$) as used in Castellani et al. (2013) capture vertical trade for NX establishments (and similarly the export intensity (X/Q) index as used in ISGEP (2008) measure verticality of trade for NM establishments) leading to a situation where the same index is capturing different phenomena under different circumstances making interpretations of its effects questionable at the establishment level. In the following sub-section, processing trade using both the *VTindex* and *VTQ* measure are compared.

3.3 Comparison of the *VTindex* and *VTQ* measure

Consider Figure 3. The ray from the origin subtended by the angle α in Figure 3 show trade points with an equi-*VTindex* which is inversely proportional to $X/Minp_0$ as given by equation (10a). The corresponding *VTQ* measure for the same volume of vertical trade is denoted by $2tan\gamma = 2 * Minp_0/Q_0$ and $\alpha + \gamma = 90°$. For a given volume of equi-*VT* shown by trade points *F* and *G* in Figure 3, a smaller trade box based on Q_0 compared to Q_1 will respectively yield a larger *VTQ* measure 2*tanγ compared to 2*tan γ'. As output of the establishment increases, the *VTQ* measure gets smaller for a given volume of vertical trade. In Figure 3, the *VTindex* at *F* is smaller than the *VTindex* at *G* since total trade at *F* is larger than at *G* although vertical trade is identical for both points. We will extend the discussion to include processing trade in the following sub-section.

<Insert **Figure 3** about here>

3.4 The *VTindex*, the *VTQ* measure and processing trade

Consider Figure 4. Trade points situated in the square in the north-east corner of the establishment production box of Figure 4 captures processing trade based on the *VTQ* measure with the size of the square again depending on the thresholds $Minp/Q$ and X/Q chosen to denote processing trade. Export processing trade establishments are “ultra” two-way or vertical trading establishments. We can use suitable threshold values to demarcate “ultra” vertical trading establishments from ordinary trading establishments. [11] If a *VTQ* measure of one is chosen as the

[11] At the country level, Amador and Cabral (2009) in cross-country analysis of vertical specialization, use average values of both exports and imported inputs across countries for a particular industry in the I-O tables as the threshold to obtain a proxy of trade related to VS activities and imported inputs in excess of this threshold then represent fragmentation trade. For a single country, the average volume of vertical trade relative to gross output, for all industries could also be used as a threshold to delineate vertical trading industries from ordinary trading industries.

threshold value; then in Figure 4, the production box can be split into four equal quadrants with trade points situated in the north-east quadrant denoted as export processing trade establishments with *VTQ* greater than or equal to one. Trade points T_1, T_2 and T_3 although with a high *VTindex* will not be considered as processing trade establishments but trade points T_4, T_5 and T_6 respectively with identical *VTindex* will be considered as vertical traders. Thus, the absolute volume of matched trade relative to production and not the volume of matched trade relative to total trade that is the appropriate measure to denote processing trade establishments.

<Insert **Figure** 4 about here>

Of course, lower threshold values for the *VTQ* measure to denote processing trade establishments will incorporate more trade points with a low *VTindex* and vice versa. The shaded area in the production box in Figure 4 depicts a region common to processing trade based both on the *VTindex* cone and the north-east corner based on the *VTQ* measure. If the dimensions of the trade box approaches that based on output, then the area of intersection of processing trade based on the two measures expand accordingly. Small volumes of vertical trade is "normal" but it is the large volumes of vertical trade relative to production that manifests itself in production networks or production sharing and past a certain threshold can be categorized as export processing trade. Vertical trade and processing trade must be linked to production and not only to total trade like the measure of Ng and Yeats (1999) based on trade in parts and components relative to total trade using SITC data. Vertical trade isolated from production may result in the case of trade point T_1 of Figure 4 where vertical trade relative to total trade is high but this trade is small relative to production and verticality of trade becomes a "non-issue".

4. Selected trade specialization measures in the establishment production box

In this section we encapsulate selected trade specialization measures in the establishment production box and compare with the measurement of *VT* introduced in this paper. *VT* as a share of gross output is defined as *VTQ* (eqn. 4) and *VT* as a proportion of total trade is defined as the $VTindex$ (eqn. 6). The $VTindex$ measures the extent of overlap between exports and imported inputs for a particular establishment weighted by total trade of the establishment. Driffield and Munday (2000) measure comparative advantage as $\log(X/Minp)$ at the 3-digit

SIC (1980) level using UK Census of Production 1984-1992 where imports from a production perspective represent an assortment of imported inputs from all industries abroad. But the $VTindex$ introduced here is directly related to $X/Minp$ (see equation 10b) in the net-import plane. Driffield and Munday (2000) measure comparative advantage as $\log(X/Minp)$ whereas vertical trade weighted by total trade (*VTindex*) for net-importing ($X < Minp$) establishments introduced in this article is a function of r_{Minp} and is directly related to $X/Minp$. Thus, comparative advantage cannot be measured by taking the ratio of exports to imported inputs in an industry. Similarly, Tucci (2001) using production data at the establishment level suggests using a direct measure of vertical specialization trade as import share of exports, $Minp/X$. Again, based on vertical trade introduced in this study, the *VTindex* is directly related to $Minp/X$ (see equation 10a) only for net-exporting ($X > Minp$) establishments and not network trade for all establishments as suggested by Tucci (2005). Thus, the variables $X/Minp$ and $Minp/X$ are related to the $VTindex$ depending on the location of the trade points of establishments in the production box.

We adopt the VS measure of Hummels et al. (2001) at the establishment level and encapsulate the VS measure in the establishment production box. To simplify matters, assume that output of establishment *i* is fixed at $\overline{Q}_i$with the dimensions of the production box given by $\overline{Q}_i$. Then the numerator of the Hummels et al. (2001) measure which we call VS trade is akin to a Cobb-Douglas function with increasing "returns" to scale, with a scale factor of "two" since each of *X* and $Minp$ is raised to the power of "one". Doubling $Minp$ and *X* leads to quadrupling of the numerator of the Hummels et al. (2001) measure which is symmetric about the bisector of the production box.[12] We focus on the trade aspectsofthe establishment in Figure5assuming fixed production (*Q*) of \$50. The rectangular hyperbolas *RR'*, *SS'* and *TT'* show iso-VS trade of 4, 9 and 16 respectively in Figure 5 (trade box located in the south-west corner of the production box). Trade points *A*, *B* and *C* in Figure 5 show identical amounts of VS trade based on Hummels et al. (2001) but total trade of points *A* and *C* are greater than that of trade point *B*. Thus, in terms of shares of total trade; points *A* and *C* have lower shares of VS trade in total trade compared to point *B* although the shares of VS trade in output is constant for all trade points on *RR'*.

<Insert **Figure 5** about here>

[12] The functional form proposed to measure *VT* at the establishment level in our study as shown by Eqn. (3) is $VT_i = 2\min(X_i, Minp_i)$. In our case, if *X* and *Minp* increase by a scalar λ, then *VT* also increase by the scalar λ depicting "constant returns to scale" of the *VT* indicator.

The index of Hummels et al. (2001) shows that point E has a higher degree of vertical specialization (0.32 = 16/50) compared to D (0.18 = 9/50) and B (0.08 = 4/50) assuming a constant Q of 50 (production box not shown in Figure 5). On the bisector, as we move away from the origin; equi-proportionate changes in X and $Minp$ of unity ($\Delta X = \Delta Minp = 1$) from trade points B to D and D to E result in increasing changes in vertical specialization trade of 5 (= 9 - 4) and 7 (= 16 - 9) respectively showing non-isotropic changes of vertical trade with respect to equi- proportionate changes in exports and imports as we move in the north-east direction.[13] This non-isotropic property[14] of VS trade also applies to other movements of trade points; for example, movements from O to F ($\Delta X = 4, \Delta Minp = 1$) and F to H ($\Delta X = 4, \Delta Minp = 1$) are identical but VS trade changes are 4 and 12 respectively for the aforementioned movements in Figure 5. In the measurement of *VT*, equi-proportionate changes in X and $Minp$ on the bisector yields equal changes in *VT*, that is, from B to D, $\Delta VT = 2$, and from D to E, $\Delta VT = 2$. Similarly, movements from O to F and F to H lead to identical changes in *VT*, that is, $\Delta VT = 2$ for each of the "identical" movements. The isotropic property of *VT* within the net-export or net-import plane renders its suitability in the measurement of vertical trade with high values of vertical trade normalized on output denoting export processing trade.[15]

What follows is a simple numerical example to illustrate the performance of the $VTindex$, *VTQ* measure and the *VS* measure of vertical specialization based on Hummels et al. (2001). It can be observed that establishments three to seven in Table 1 have *VS* trade that exceeds total trade of the establishment unlike *VT* which is always less than or equal to total trade of the establishment.

<Insert **Table 1** about here>

Hummels et al. (2001) also introduced a measure called the *VS* share of exports and at the establishment level;

$$\frac{VS}{X} = \frac{X * M_{inp}}{Q} * \frac{1}{X} = \frac{M_{inp}}{Q} \tag{11}$$

[13] In fact along the bisector of the trade box, equi-proportionate changes of one unit for X and $Minp$, that is, $\Delta X = \Delta Minp$=1 starting from the origin results in unequal changes in VS trade, that is, $\Delta VS_1 = 1$, $\Delta VS_2 = 3$, $\Delta VS_3 = 5$, $\Delta VS_4 = 7, \ldots, \Delta VS_n = n - 1 + n = 2n - 1$.

[14] Non-isotropic here means that the Hummels et al (2001) index does not faithfully represent distance with equi-distant movements or changes resulting in non-equal changes of VS trade.

[15] In the case of movement of trade points across the bisector of the establishment production box; the initial trade point is reflected across the bisector to a symmetrical point with identical *VT* and changes are then considered to preserve the isotropic of *VT*.

The *VS* share in exports is isotropic across the production box unlike the *VTQ* measure which is only isotropic within the NX and NM plane. In the context of the production box; the *VS* share of exports maps all trade points to the horizontal axis irrespective of whether the establishments are net-exporters or net-importers and normalizes the imported inputs by gross output (Q). Assuming all trade points have identical gross output, the *VS* share of exports is measured as the tangent of the angle subtended by imported inputs, that is, the imported inputs distance divided by gross output. This offshoring index is bounded by [0, 1) and widely used in studies to measure vertical trade. In Figure 6a, trade points *A*, *B* and *C* are mapped to points a, b and c respectively on the horizontal axis with tangent of the angles α, β, and γ depicting the respective offshoring index. The *VS* share of exports does not directly take into account the exporting side of establishments which Amador and Cabral (2009) attempted to rectify at the industry level. For example, consider trade point C in Figure 6a. All trade points on the vertical line through point *C* yield an identical *VS/X* measure but establishments with trade points in the north-east quadrant have a greater embodiment of exports compared to points in the south-east quadrant of the box.

<Insert **Figure 6a** and **Figure 6b** about here>

Similarly, the *VS* share of imports ($VS/\,Minp$) is equal to *X/Q* or the export-intensity index at the establishment level and is a mapping of trade points to the vertical axis in the production box with the tangent of the angle subtended by exports denoting export-intensity and is bounded by [0,1] as shown in Figure 6b. The *VS* share of imports or export-intensity index is less "famous" in the measurement of vertical specialization compared to the *VS* share of exports or the offshoring index *Minp/Q*. As shown in Figure 4, the *VTQ* measure maps trade points in the NX plane to the horizontal axis resulting in the *VTQ* measure, $2 * Minp/Q$, and the *VTQ* measure maps trade points in the NM plane to the vertical axis resulting in the *VTQ* measure, 2*(*X/Q*). Thus, the *VTQ* measure incorporates both the VS share of exports and imports, and is twice the offshoring index *Minp/Q*, for net exporting establishments whereas for net importing establishments, the *VTQ* measure is twice the export intensity index *X/Q*, and measures simultaneously the "overlap" of exports and imported inputs. Individually, the often used *VS* share of exports, *Minp/Q*, does not incorporate the exporting side of establishments and thus does not fulfil the condition stipulated in Hummels et al. (2001, p. 77) that "at least one country must use imported inputs in its stage of the production process, and some of the resulting output must be exported".

In the appendix of Ozler and Yilmaz (2009), trade orientation of a 3-digit SIC industry whether as an export-oriented (EO) or import-competing (IC) sector respectively is defined by the export-output ratio or import-penetration rate above 15 per cent and others are classified as non-traded (NT) sectors. In cases where both the export-output ratio and import-penetration ratio exceeds 15 per cent; the sector is an EO (IC) sector if the former ratio is larger (smaller). The establishment production box framework can be used to represent trade orientation as proposed by Ozler and Yilmaz (2009) but at the establishment level.

The dimensions of the production box will be given by the output for establishment *i* denoted as Q_i. The classification of Ozler and Yilmaz (2009) with respect to trade orientation of industries can be applied at the establishment level and trade can be embedded in a production box. Figure 7 demarcates trade points for export-oriented establishments in rectangle *TABR* where $X_i > 0.15Q_i$ and $Minp_i < 0.15Q_i$ with Q_i denoting gross output of establishment *i*. The points *R* (=$0.15Q_i$) and *S* (=$0.15Q_i$) will be different for each establishment *i* depending on Q_i. The designation of establishments whether as non-traders, EO or IC is weighted by gross output of establishment *i*. Import competing (IC) establishments are shown as trade points in rectangle *BCUS* where $X_i < 0.15Q_i$ and $Minp_i > 0.15Q_i$. Trade points within the square *ORBS* (with dimensions equal to $0.15Q_i$) represent the non-traders. In cases where both $X_i > 0.15Q_i$ and $Minp_i > 0.15Q_i$, then $X_i/Q_i > Minp_i/Q_i$ shows export-oriented establishments and $X_i/Q_i < Minp_i/Q_i$ shows import competing establishments corresponding to $X_i/Minp_i > 1$ and $X_i/Minp_i < 1$ in the establishment production box framework. Thus, in the square *ABCD*, trade points of establishments located above (below) the bisector of the production box are denoted as export-oriented establishments (import-competing).

<Insert **Figure 7** about here>

Trade orientation as defined by Ozler and Yilmaz (2009) has two shortcomings. Firstly, if X/Q and $Minp/Q$, for example, are respectively 85 and 86 per cent for a particular establishment; in an era where production is disintegrated spatially, categorizing the establishment as import competing is dubious since the establishment is probably an export processing establishment. Measuring trade orientation (using *Annual Survey* *of Manufacturing Industries* based on SIC production data) of establishments, as either EO or IC "overlooks" ultra-vertical traders or export processing trade which simultaneously uses high volumes of imported inputs and exports high volumes of output. Trade points located to the north-east of the equi *VTQ* "L-shaped" line *FG* in Figure 7 show the export-processing nature of establishments. Secondly, based on production data, imports are an assortment of imported inputs from all industries abroad and need not compete directly with local production of the ("final") commodity which can be exported or used locally and therefore trade orientation need not necessarily mean import competing when imported inputs penetration is high (many different imported inputs mapped into a single SIC category of output and exports). [16] Sjöholm (1999) also stresses the importing of input goods or importing intermediates when using industrial production data and Aristei et al. (2011) refers to the importing of intermediates at the establishment level as foreign sourcing. Identifying trade orientation of establishments and industries within the context of import-competing industries using *Annual Surveys of Manufacturing Industries* based on SIC production data needs to be conducted with caution.

Sjöholm (1999), ISGEP (2008) and others study productivity and internationalization of establishments using variables like export intensity and import intensity. But the vertical trade measure, *VTQ*, introduced in this study is a function of imported input intensity (export-intensity) for net exporting (importing) establishments. A given horizontal line in the production box denotes a given level of exports, say X_0. A trade point with exports of X_0 located on the upper part of the vertical axis of the production box denotes exporting without the use of imported inputs like production of complete value chains in a country in neo-classical theory without foreign value added.[17] Here export intensity (X/Q) measures export orientation of the establishment. But if the same X_0 has imported inputs in the north-east quadrant of the production box and is located below the bisector (net-importing establishments), then high export-intensity refers to high vertical or processing trade ($VTQ > 1$). Thus, the variables export intensity and import intensity (offshoring) capture different phenomena depending on the location of the trade points in the production box and the interpretation of the effects of these variables is not uniform.

[16] Some studies, for example, Takii (2005, p. 528) also measure import competition as the ratio of total import to total output of products with imports in surveys of manufacturing establishments on production, referring to imported inputs and imported inputs does not necessarily reflect import competition of an industry.

[17] Under the assumptions of neo-classical economics, the trade point of establishments collapses to points on the vertical axis in the production box without foreign value added in production.

5 Conclusions

This paper discuss the differences between imports and imported inputs respectively based on SITC and *Surveys of Manufacturing Industries* based on ISIC data and that revealed comparative advantage indices based on the latter data does not reflect comparative advantage as measured by the former data. Vertical trade (*VT*) is introduced as the overlap of exports and imported inputs and framed geometrically in the production box of establishments. We introduce two indices, the share of vertical trade in gross output measure (VTQ) and the share of vertical trade to total trade index ($VTindex$) at the establishment level and compare them to other selected indices in international including the vertical specialization index of Hummels et al. (2001) which is computed using input-output tables at the industry level. The $VTindex$ is akin to the Grubel-Lloyd index of intra-industry trade. The *VTindex* is inversely related to $X/Minp$ in the NX plane and $Minp/X$ in the NM plane although Driffield and Munday (2000) use $X/Minp$ to measure comparative advantage and Tucci (2005) suggest using the $Minp/X$ to measure involvement in production networks irrespective of the location of trade points or different circumstances of the establishments. The non-isotropic property of the Hummels et al. (2001) measure of vertical specialization trade is highlighted compared to the isotropic property of VT for trade points within the net-export and net-import plane in the establishment trade box.

The VTQ and $VTindex$ are framed in a production box of establishments and compared with earlier measures of export oriented and supposedly import substitution industries elucidating the export processing nature of certain industries. VTQ is twice the imported input intensity ($2*Minp/Q$) in the net export plane and twice the export intensity ($2*X/Q$) in the net import plane. The variables X/Q and $Minp/Q$ is commonly used in the trade and productivity literature to measure export performance and offshoring activities respectively but in this article the former index measures vertical trade intensity for net-importing establishments and the latter index measures vertical trade for net exporting establishments. Thus, the same index is capturing different phenomena under different circumstances making interpretations of its effects questionable.

We show that high degrees of vertical trade or “ultra” vertical trade (as defined in this article) relative to production depict export processing trade. The consequences are different when exports occur naturally as a vent for surplus production produced almost from scratch domestically with minimal foreign value added and when exports occur as part of a global production network with significant amounts of imported inputs. The former reflects comparative advantage but the latter arising from fragmentation of production or vertical specialization in global production networks need not necessarily reflect comparative advantage in production of the export good. High amounts of overlap between exports and imported inputs can be attributed to export processing activities of establishments and does not necessarily indicate comparative advantage in production when focussing only on the exporting side of trade. When headquarters of multinationals “control” the trade scene by providing directives to affiliates and significant production fragmentation as in export-processing occurs; we are not quite sure if the “learning by exporting” hypothesis or “self-selection” of the more productive establishments into exporting is more “truthful” since the export intensity variable carry different meaning at different locations in the establishment production box. In other words, with the definite presence of vertical foreign direct investment and vertical trade, the effect of ex porting *per se* on productivity is ambiguous. Further empirical research can utilize the vertical trade measure introduced in this article to investigate the effects of exporting on productivity in the definite presence of export processing trade.

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Figure 1 Vertical trade in the production box

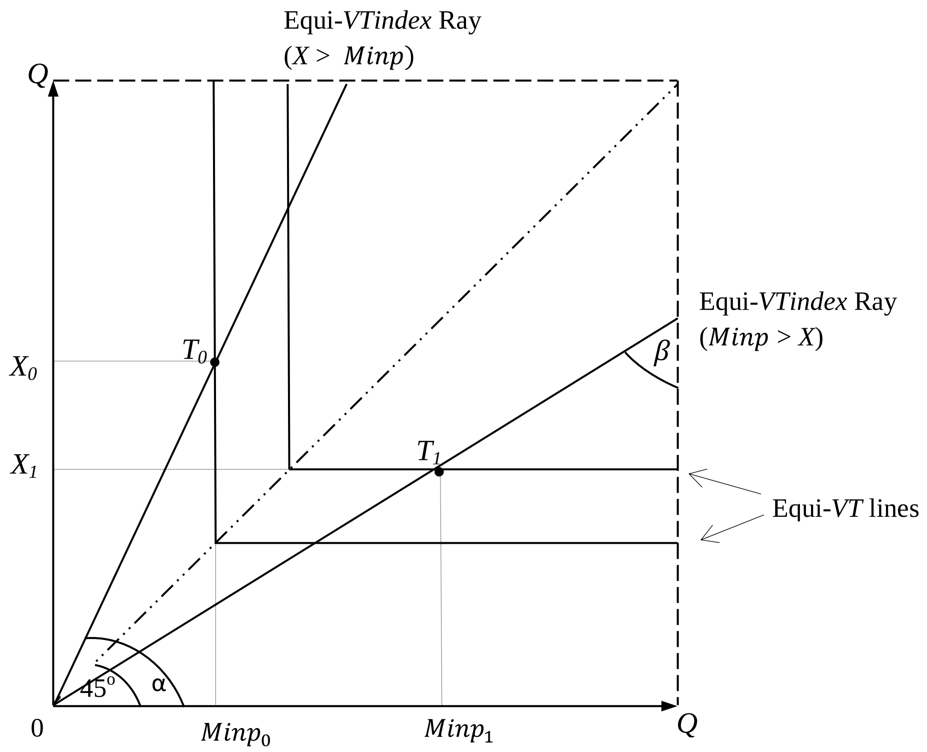


Figure 2 The *VTQ* measure in the establishment production box

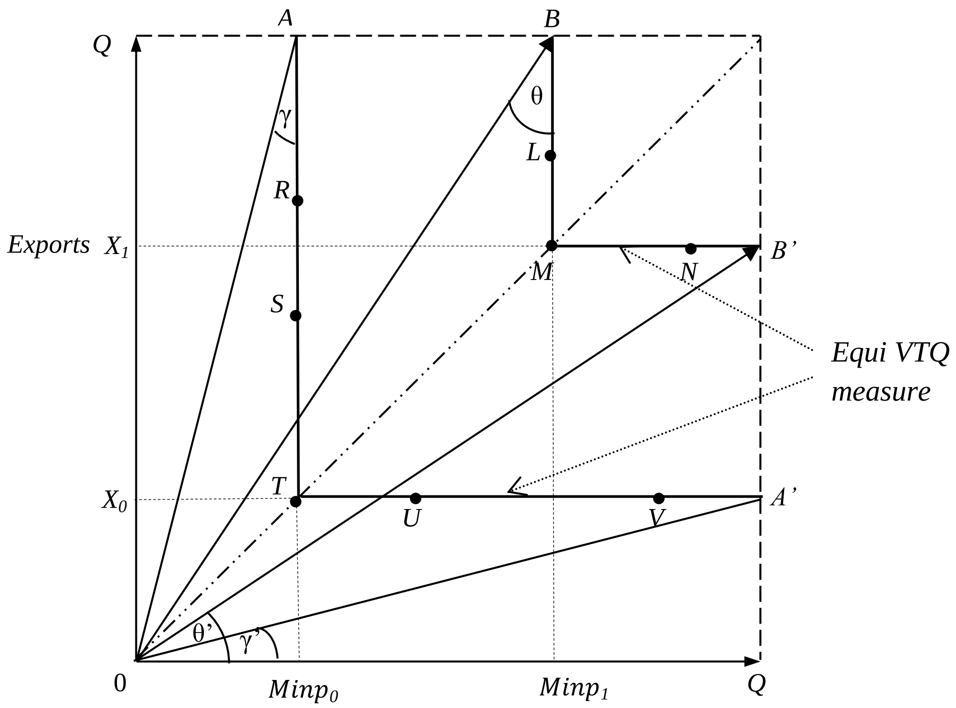


Figure 3 The *VTQ* measure and *VTindex* for a given volume of *VT*

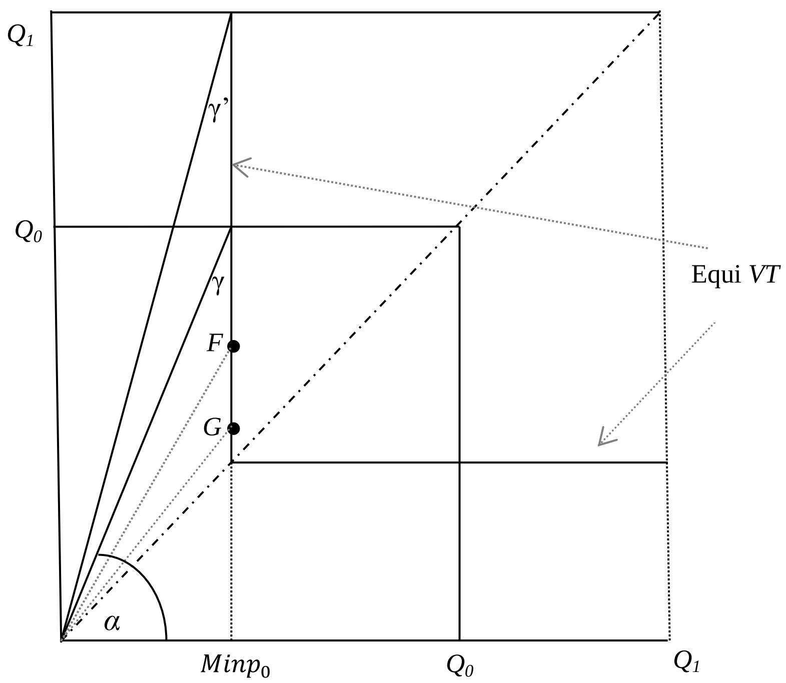


Figure 4 Ultra vertical traders in the production box

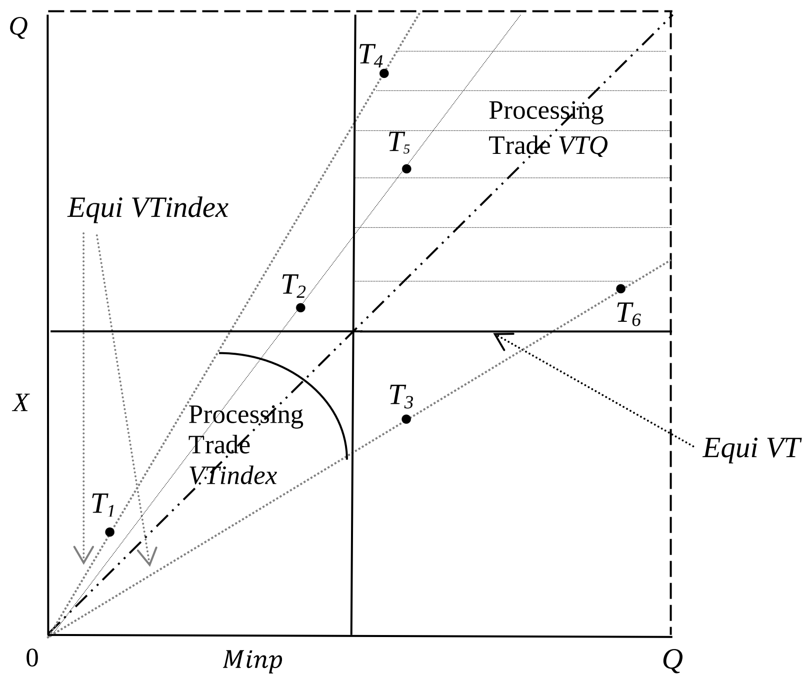
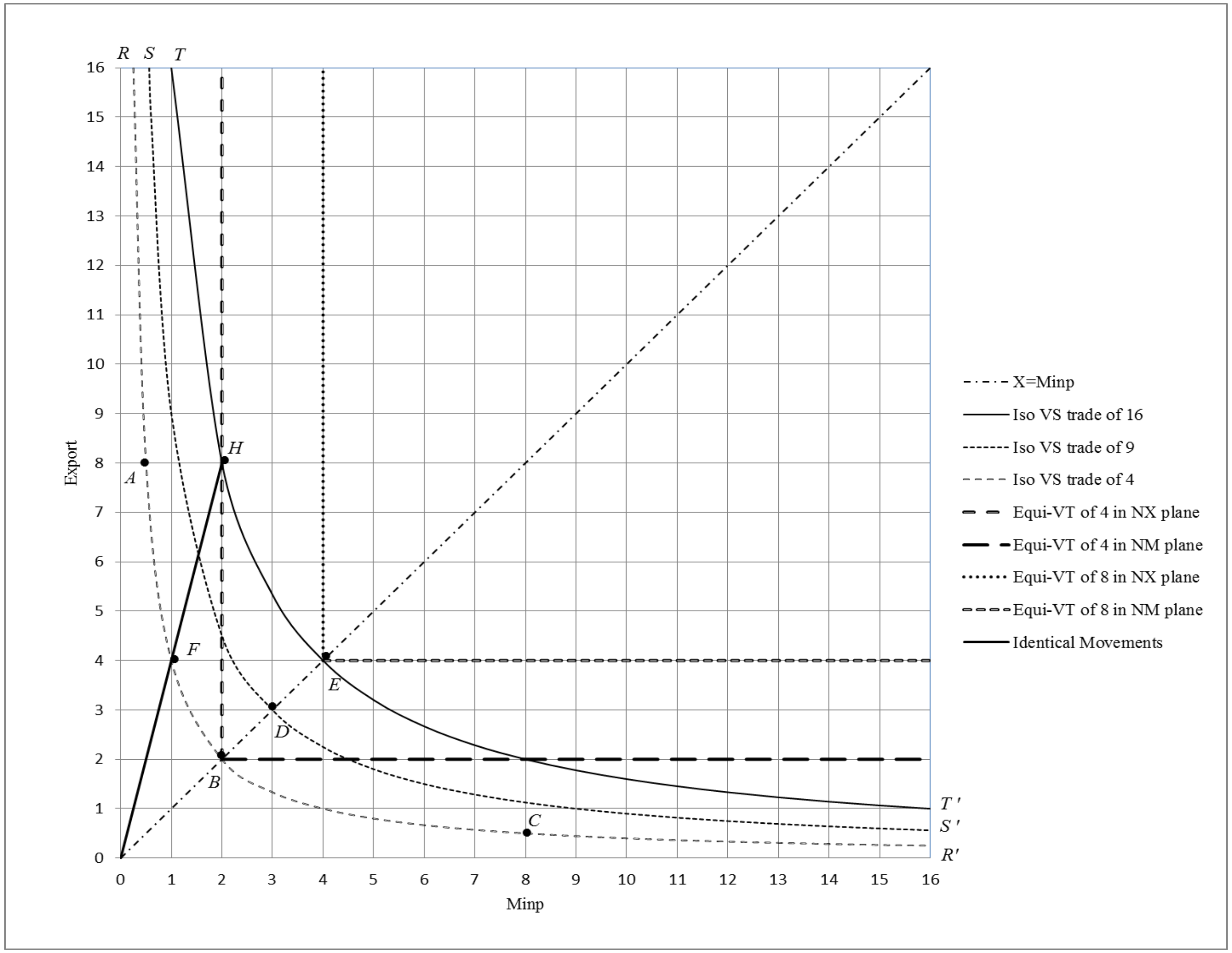


Figure 5 *VS* and *VT* trade in a trade box



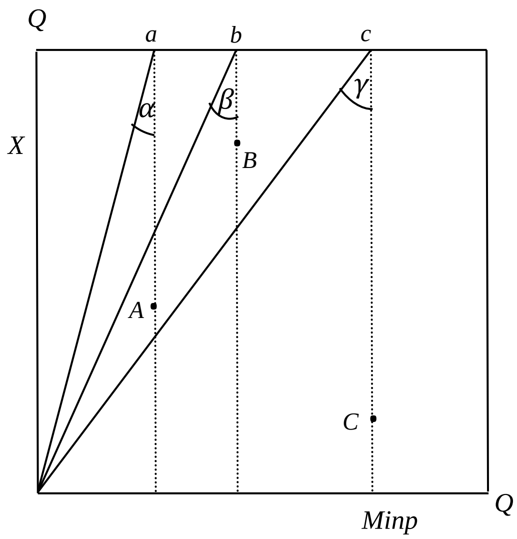


Figure 6a VS share of Exports

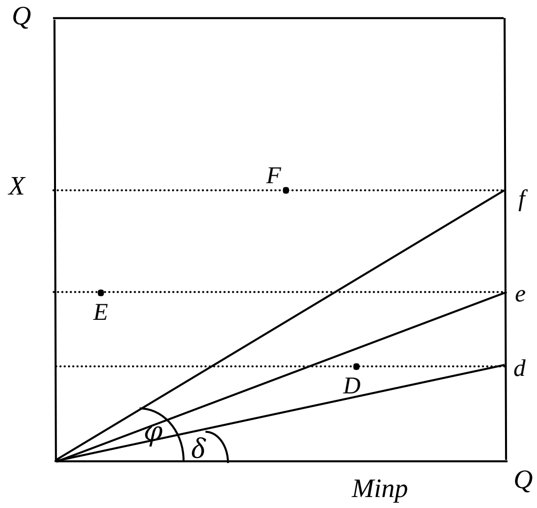


Figure 6b VS share of Imports

Figure 7 Trade orientation of establishments in the production box

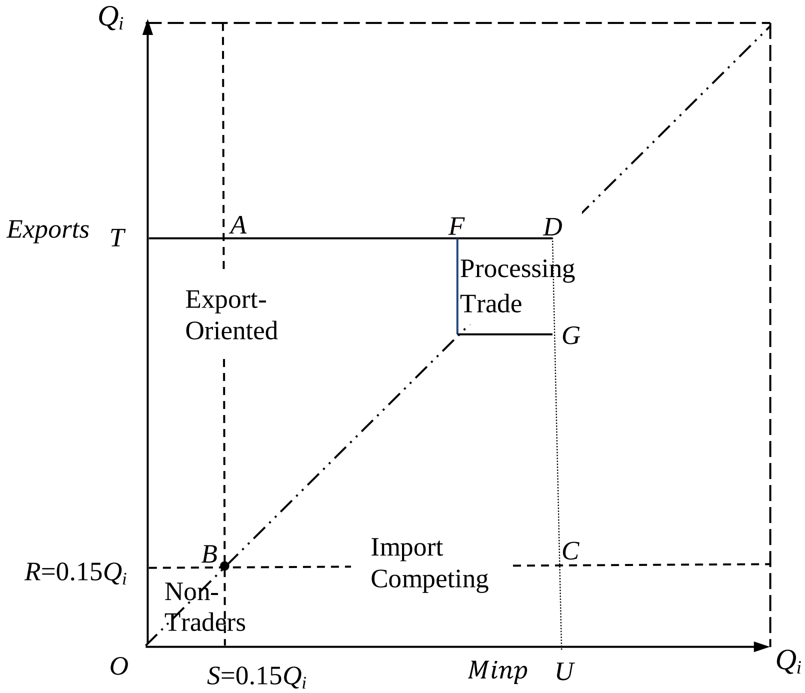


Table 1 Numerical example of vertical trade *(VT)*, *VTindex*, *VTQ*, VS trade, vertical specialization (*VS*) , *VS* share of exports and *VS* share of imports

Establishment	*Q*	*X*	*Minp*	*VT*	*VT index*	*VTQ*	*VS trade (X*Minp)*	*VS (X*Minp)/ Q*	*VS share of Exports (Minp/Q)*	*VS share of Imports (X/Q)*
1	10	2	1	2	0.67	0.20	2	0.2	0.1	0.2
2	10	1	2	2	0.67	0.20	2	0.2	0.2	0.1
3	10	3	3	6	1.00	0.60	9	0.9	0.3	0.3
4	10	3	2	4	0.80	0.40	6	0.6	0.2	0.3
5	10	6	4	8	0.80	0.80	24	2.4	0.4	0.6
6	10	8	9	16	0.94	1.6	72	7.2	0.9	0.8
7	100	80	90	160	0.94	1.6	7200	72.0	0.9	0.8