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Transport costs and new economic geography

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Abstract

This paper uncovers some little-known properties of the iceberg transport cost functions which are employed in some new economic geography models. In particular the behaviour of the delivered prices generated by the Krugman iceberg specification is very different to those generated by the original Samuelson iceberg model, and these differences require careful interpretation of the outcomes of the explicitly spatial versions of new economic geography models. If the iceberg model is viewed simply as transport costs, then these properties can be shown to be largely implausible when compared with a wide range of empirical evidence. At the same time, even if the iceberg model is viewed as capturing a range of different distance costs, there are still grounds for cautiousness in the way that inferences are made from these models when moving from theory to reality or policy analysis.

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1. Introduction

Geography and space is introduced into new economic geography models in the form of an iceberg transport costs function, in which part of the goods to be delivered are consumed by the very act of transporting. Following Krugman's (1991a, 1991b) initial application of the iceberg cost assumption to problems of economic geography, the use of the iceberg transport cost formulation is now standard practice in most new economic geography models. The major reason for the use of this formulation is that it allows for a direct mathematical manipulation of distance costs functions in a manner which is consistent with the modelling techniques allowed for by Dixit-Stiglitz (Dixit and Stiglitz, 1977) functions of monopolistic competition. As Krugman (1998) points out, although the explicitly spatial iceberg assumption is itself implausible, the adoption of it is made entirely on the basis of analytical tractability rather than on the basis of any observed reality. As such, the major justification for the iceberg assumption is not observational or empirical but analytical, in that it is a 'technical trick' employed for reasons of 'modeling convenience', thereby avoiding '... the need to model an additional industry' (Krugman 1998, 165).[1]

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1 The assumption of the iceberg function amounts to assuming that the technology used to produce a good is identical to that used in order to transport the good (Neary, 2001). The reason for this is that the iceberg function yields log-linear transport costs, and when this is added to the log-linear demand functions yielded by CES preferences, only the levels, and not the elasticities of the demand functions are changed. As such, this must be a special case (Neary, 551).

As long as it is accepted that the iceberg functions are employed only for reasons of analytical tractability then this is not really problematic. On the other hand, however, where commentators begin to use these models in order to provide real-world insights then the issue becomes rather more complicated. The reason for this is that there are some little-understood properties of the iceberg transport cost function, which mean that any empirical inferences made on the basis of the models must necessarily be treated in a rather careful manner. Although these properties may be well-understood by the proponents of these models, it would be reasonable to suggest that most observers are probably unaware of these subtle issues. The usefulness of clarifying these properties is therefore, that when moving from theory to reality, it allows for clarification both as to what can reasonably be inferred from such models, and also how the insights of such models might better be interpreted.

The aim of this paper is to explain the subtle nature of these iceberg properties, in order to help clarify both the types of inferences that can justifiably be made from these models, and also to indicate some of the limitations of these models.

At this point it is necessary to explain that this paper does not try to modify or redefine new economic geography by grafting on new, additional or alternative assumptions. Rather, it is simply clarifying the theoretical nature of the iceberg assumption as it is currently employed in some new economic geography models, and highlighting some of the problems which are therefore faced in the interpretation of such models in the light of empirical evidence or policy analysis. Importantly, the issues discussed in this paper refer only to the explicitly spatial versions of new economy models in which geographical distance is an explicit variable in the model (Krugman, 1991a, b, 1993; Fujita and Krugman, 1995; Fujita and Mori, 1996, 1997; Fujita et al., 1999a, 1999b; Stelder, 2002). The argument here does not relate to the non-spatial versions of new economic geography (Krugman and Venables, 1995, 1997; Venables, 1996; Ottaviano and Thisse, 2001, 2003) in which distance is not an explicit variable.

In order to develop the argument and to clarify the various theoretical, empirical and interpretative issues associated with iceberg costs, the next section first begins by explaining the traditional logic of the original Samuelson (1952) iceberg transport cost function, as employed both in traditional neo-classical trade theory and also in new trade theory. Section 3 explains how the traditional iceberg concept has been altered and then adapted within the new economic geography models, and reveals certain fundamental properties of this iceberg adaptation which have been largely ignored. In section 4, the properties of the iceberg model are contrasted with both other theoretical specifications of transport costs and also empirical observations of distance-transport cost functions. On the basis of these comparisons it becomes clear that how the insights of these new economic geography models are interpreted in the light of empirical work is not as straightforward as may first appear. The reason for this is that there are grounds for believing that the analytical results of the new economic geography models may well be very sensitive to the structure of the iceberg function. Section 5 considers the effects of treating iceberg transport costs as being comprised of a range of different observable and unobservable distance costs. As will be demonstrated, this approach itself also raises further problems. The conclusion is that while new economic geography models have gone further than any other framework in developing a general equilibrium approach to analysing spatial economic phenomena, an awareness of limitations of the basic iceberg assumption suggests that a level of caution is required when considering the geographical insights of these models, particularly in the light of empirical work or other theoretical models.

2. The Samuelson iceberg transport cost function

The iceberg formulation of transportation costs was first employed by Samuelson (1952). At the time it was first introduced as an analytical device, the attractiveness of employing this particular description of transportation costs was that it circumvented the problems associated with defining costs explicitly in geographical terms, as was being attempted by others at the time (Isard, 1956). In classical and neo-classical international trade models of the 1950s, which were essentially aspatial, this analytical device greatly simplified trade analysis by treating distance and transportation costs in exactly the same way as tariff costs. The logic of the Samuelsonian iceberg formulation can be explained in the following manner:

Suppose there are two markets, a home market H and a foreign market F. If a good x is produced in the home market H with a value of V_{XH}, and some of the good is consumed by the act of shipment, the value of the good which actually arrives in the foreign market is denoted as $\tau_x V_{XH}$, where 1-τ_x is the proportion of the good x consumed by the process of transportation from H to F. In order to determine the relative prices of the goods in the home market P_{XH} and in the foreign market P_{XF}, it is necessary to remember that the value of the good in the home market V_{XH} is the product of the domestic price per ton of the good P_{XH} multiplied by the tonnage of good x being shipped from the home market M_{XH}. Now, in the act of international shipment, although the price per ton of x paid by the foreign consumer to the domestic producer is P_{XH}, for each ton purchased at H, the total weight of good M_{XF} actually arriving in the foreign market F is only $\tau_x M_{XH}$ tons. In other words, the foreign price per ton P_{XF} actually paid by the foreign consumer is given as:

$$\mathrm{P_{XF}} = \mathrm{P_{XH}}(\mathrm{M_{XH}}/\mathrm{M_{XF}}) = \mathrm{P_{XH}}/\tau_{\mathrm{X}} \tag{1}$$

where P_{XF} represents the cost to the foreign consumer of acquiring a ton of good x in the foreign market F. Similarly, for a foreign-produced good y of mill price P_{YF} per ton in the foreign market, the home market price of good y is denoted as:

$$\mathrm{P_{YH}} = \mathrm{P_{YF}}/\tau_{\mathrm{Y}} \tag{2}$$

where τ_y represents the proportion of the good y not consumed in the process of transportation from F to H. Diagrammatically, these two situations can be represented by Figure 1.

As can be seen in Figure 1, the iceberg formulation depicts transportation costs as a step-wise discontinuity between the home and foreign prices of the respective goods, in which the extent of the discontinuity varies in proportion to the value of τ. Within any

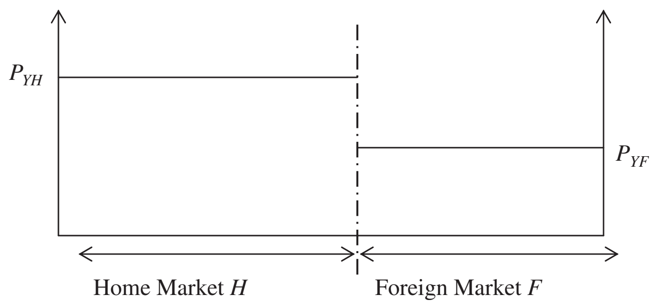

Figure 1. Iceberg prices of foreign-produced goods in foreign and home markets.

part of an individual country the prices of each of the goods are invariant. In other words there is no spatial pricing which is distance related. As such, there is no economic geography within the individual country, which is essentially spaceless. On the other hand, moving across an international trade border results in a stepwise price increase for each good. Once again, however, there is no explicitly geographical aspect to this discontinuity. Larger or smaller stepwise functions can be assigned as desired. For example, if the home and foreign countries are adjacent to each other, it may be assumed that τ is rather small, such that the stepwise discontinuity is small. On the other hand, if the two countries are far apart, it may be assumed that τ is rather large, such that the stepwise discontinuity is large. These assumptions, however, are essentially arbitrary, in that what is explicitly not undertaken, is the formulation of any specific continuous relationship between the level of τ and the distance between the two countries. As such, transportation costs can be characterized and analysed in exactly the same way as a one-off trade tariff. Moreover, avoiding the specification of any specific relationship between transportation costs and distance means that transportation costs and trade tariffs can now be combined into a single parameter for ease of analysis. Geography is assumed away, as in traditional models of international trade.

A second feature of the simple Samuelson iceberg model is that the transport cost per tonne is invariant with respect to the tonnage of material delivered.

In the more recent 'new international trade' models most closely associated with the work of Krugman (1994) and Helpman and Krugman (1985), the Samuelsonian iceberg device is also adopted in conjunction with Dixit-Stiglitz (1977) descriptions of monopolistic competition and economies of scale. As with traditional classical and neo-classical trade models, these 'new international trade' models are still essentially aspatial, in that no specific continuous relationship between iceberg transportation costs and distance is specified. Economic geography as such still does not exist in these models.

3. Iceberg transport cost functions in new economic geography models

A major intellectual shift occurred with the work of Krugman (1991a, 1991b) who adapted the functional forms employed in 'new international trade' models to the case of geographical space. The Dixit-Stiglitz (1977) functions are still employed, as are increasing returns to scale functions. However, the single most important technical innovation which allowed a shift from 'new international trade' models to 'new economic geography' models was the specification of iceberg transport cost functions as continuous distance functions. Krugman (1991a, 1991b) redefined the aspatial Samuelsonian iceberg function into an explicitly geographical distance-related function. The Krugman (1991a, 1991b) definition of iceberg transport costs is:

$$V_d = V_o \mathrm{e}^{-\tau D} \tag{3}$$

whereby V_o is the value of the good at the origin location, τ is the iceberg decay parameter, D is the haulage distance, and V_d is the quantity of good actually delivered at the delivery location d. In this formula, τ represents the proportion of the remaining quantity of the good which 'melts' away each kilometre. Note that there is a subtle change here from the Samuelsonian version of the iceberg whereby (1-τ) represented the proportion which melts away, and τ represented the remaining proportion of the good. If we set $W = V_d/V_o$ then equation (3) can be re-written as:

$$W = \mathrm{e}^{-\tau D} \tag{4}$$

Taking logs of both sides of equation (4) and differentiating both sides with respect to D gives:

$$\frac{1}{W}\frac{\partial W}{\partial D} = -\tau \tag{5}$$

In other words, as the haulage distance increases, the (negative) rate of growth of the value of good V_d actually delivered, divided by the original source value V_o of good produced, remains constant. In other words, τ represents the constant rate of (iceberg) distance-decay. This can be represented diagrammatically as in Figure 2.

It can be seen in Figure 2 that the absolute quantity of distance-decay per kilometre, represented by the slope of the function, falls as the haulage D increases. The vertical distance between the perforated line at level V_o and the iceberg function, represented by the continuous strictly convex curve, represents the absolute quantity of goods which 'melt' away over any given haulage distance. The convexity of this function suggests that, *prima facie*, the marginal costs of transportation, as represented by the quantity of good that melts away, falls with increasing distance. Such a formulation therefore appears to be broadly consistent with empirical observations of transportation economies of distance, in which the delivered prices of goods are generally concave functions of distance. This, however, is not the case, because V_d does not represent the delivered price of the good. To see this, it is necessary to convert the Krugman (1991a, 1991b) iceberg formulation into a delivered price function in a manner analogous to the Samuelson (1952) function.

In order to convert an iceberg transport costs function into a delivered price function, we must ask how much it costs a consumer at a given distance D from a production location to consume a given quantity of a good, and how this consumption cost varies with D. Here it must be remembered that the origin value of a good being shipped, denoted above as V_o, is defined as the product of the origin mill price P_o per ton of the good, multiplied by the tonnage of good M_o leaving the production location. On the other hand, the destination value of the good defined in terms of the origin value, denoted above as V_d, is given as the product of the origin mill price P_o per ton of the good, multiplied by the tonnage of good M_d actually arriving at the consumption destination. In order to determine the delivered price of the good allowing for the distance-decay, as with the

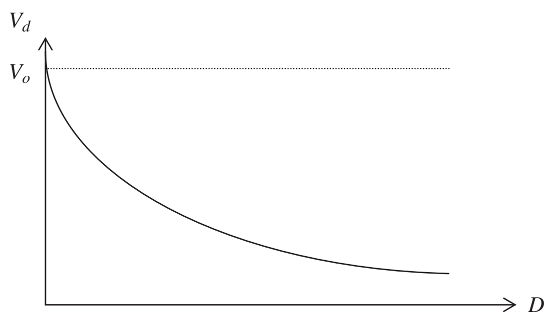

Figure 2. Iceberg distance-decay.

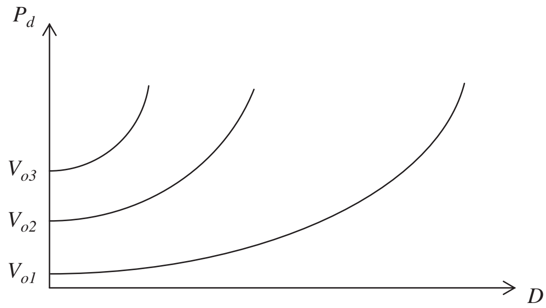

Figure 3. The relationship between the iceberg distance costs formulation and the delivered price per ton.

Samuelsonian iceberg function, the cost of purchasing one ton of a good of mill price P_o per ton shipped at a distance D can be written as:

$$P_d = P_o(M_o/M_d) \tag{6}$$

where P_d represents the price per ton of the delivered good. If it is recalled from equations (1) and (3) that (M_o/M_d) can be rewritten as $(V_o/V_o\mathrm{e}^{-\tau D})$, then this gives:

$$P_d = P_o(V_o/V_o e^{-\tau D}) = P_o/\mathrm{e}^{-\tau D} = P_o\mathrm{e}^{\tau D} \tag{7}$$

Taking the first and second order conditions of equation (7) with respect to distance gives:

$$\frac{\partial P_d}{\partial D} = \tau P_o\, e^{\tau D} \tag{8}$$

and

$$\frac{\partial^2 P_d}{\partial D^2} = \tau^2 P_o\, e^{\tau D} \tag{9}$$

From equations (8) and (9) it is seen that the relationship between the delivered price of the good and the haulage distance, described by equation (7), is therefore represented diagrammatically as in Figure 3.

The second property of the iceberg model can be seen by taking the cross-partials of equation (8) with respect to the origin price of the good thus:

$$\frac{\partial\left(\dfrac{\partial P_d}{\partial D}\right)}{\partial P_o} = \tau\, e^{\tau D} \tag{10}$$

As can be seen in equation (10), in the Krugman iceberg model the level of distance-delivered price convexity increases with the value of the good being shipped, for any given value of τ. This property is depicted in Figure 3, where by comparing the delivered prices for three goods of origin prices V_{o1}, V_{o2} and V_{o3}, where $V_{o3}>V_{o2}>V_{o1}$, it can be seen that the delivered price of the good rises with distance at a greater rate for goods with higher origin prices than for goods with lower origin prices.[2]

2 Ottaviano and Thisse (2003, 19) argue that the iceberg assumption implying that a rise in the price of a good leads to a proportional rise in its transport cost is unrealistic. However, if we adopt a logistics-costs definition of transport costs (McCann, 1993, 1998), which also includes the inventory holding costs as well as the movement costs involved in transportation, then transport costs are always seen to vary with the square root of the price of the good. This price varying assumption can actually therefore be argued to be somewhat realistic.

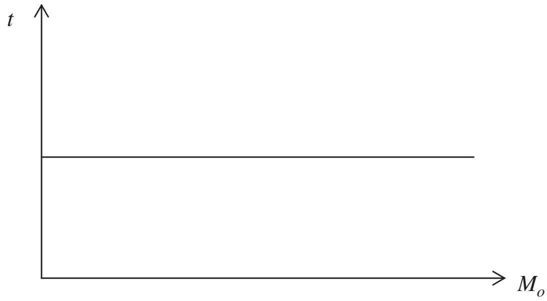

Figure 4. The relationship between the iceberg distance costs formulation and the transport cost per tonne-kilometre.

A third feature of the Krugman iceberg model, is that for any given haulage distance and for any given mill price per ton, the transport cost per ton-kilometre t is *invariant* with respect to the weight of material M_o initially hauled from the origin. This is depicted in Figure 4.

Although in absolute terms the total weight of material which is consumed in the act of transportation is directly related to the weight of material initially hauled from the origin, this level of consumption is exactly in proportion to the origin weight. The outcome of this is that the transport cost between any two locations is always a constant fraction of the f.o.b. price irrespective of the quantity shipped between the two locations, thereby preserving the constant elasticity of demand (Krugman 1998, 165). The invariance of the transport rate per tonne-kilometre in Krugman's explicitly spatial version of the iceberg model is therefore directly parallel to the behaviour of the simple Samuelsonian aspatial iceberg formula, in which the transport cost per tonne is also invariant with respect to the total tonnage shipped.

In new economic geography models, these subtle properties of the iceberg model play a fundamental analytical role. The convex-with-distance delivered-price property of the iceberg transport costs acts as a natural break and counterbalance to any localized (agglomeration) economies of scale, thereby imposing spatial market limits on production. As such, spatial market areas can be delineated around the hinterland of each urban location. Without an iceberg transport costs structure, the parameter space for which the 'no black hole' condition[3] holds (Fujita et al., 1999a; Neary, 2001) will become greatly reduced.

4. Problems of interpretation

The three properties of the Krugman iceberg model, namely that the delivered price of the good is (i) convex with respect to the distance, (ii) directly proportional to the original price of the good, and (iii) the transport rate per ton-kilometre is independent of the quantity shipped, are clearly very different to the properties normally ascribed to transport costs functions in most models of spatial pricing or transportation economics. Prior to the 1991 advent of new economic geography, the theoretical structure

3 Moreover, as Neary (2001, 542) points out, the 'no-black-hole' condition is only an assumption, and is not a property of the model (Fujita et al. 1999a, 58–59).

(Bruce Allen, 1977) of transport costs in most spatial economic models reflected the observed results of all the wide-ranging empirical work on transport rate structures (Bayliss and Edwards, 1970; Jansson and Shneerson, 1985, 1987; Tyler and Kitson, 1987; Savage, 1997) which almost universally reported economies of distance and scale in transportation. Therefore, in most models of spatial pricing or transportation economics, transport economies of scale mean that; (i) the delivered prices of goods are typically assumed to be concave with distance, and (ii) the transport rate per ton-kilometre is typically assumed to be convex with respect to both haulage distance and the haulage quantity.[4]

These fundamental differences between the properties of the Krugman iceberg assumption and more traditional transport cost functions, therefore lead to something of a problem of interpretation and inference. In particular, these differences raise the question of the extent to which the novel predictions of the new economic geography models over earlier approaches, are themselves dependent on, or sensitive to, the nature of these very different iceberg assumptions. Evaluating this, however, is very difficult because it is almost impossible to provide direct comparisons between models with the iceberg assumption and those with other sets of transport costs assumptions embedded in them. In part this is because these more traditional transport costs functions are analytically incompatible with new economic geography models. Also, however, this is because in models of new economic geography which employ the iceberg assumption, transport costs are simply discussed in terms of being 'high' or 'low', whereas in more traditional models, the properties of the transport cost functions determine the analytical outcomes. What is almost never discussed in models of new economic geography, is whether the *properties* of the iceberg assumption with respect to either haulage distance or quantity may affect any of the analytical results.

On this point, Neary (2001) argues that the detailed results of the new economic geography research programme do rely on the 'seemingly innocuous' (Neary 2001, 550) properties of the iceberg assumption, and as such, the new economic models may be sensitive to these assumptions. Indeed, there are good reasons why this might be so. In almost all models involving transactions costs (Hahn 1971; d'Aspremont et al., 1979; Haurin et al., 1994; Muellbauer and Murphy, 1997; McCann, 1998), the analytical solutions generated by optimization techniques are seen to depend crucially on the marginality conditions, and there is no reason to assume that this case is any different. Transport costs are simply one form of transactions costs, with the unique additional characteristic that their level is explicitly related to the geographical distance. In other words, the particular definition of the transport costs function we employ represents the specific way in which geography is incorporated into the economic model. Therefore, if the functional definition of the transportation costs is changed, then the predictions of the model may well change.

4 The traditional explanation for such concave transportation costs functions rested on the static distinction between fixed terminal costs and variable movement costs (Thorburn, 1960; Alonso, 1964). Although there are some limited cases relating to zoning and service quality where the transport rate per ton-mile is invariant with respect to the quantity shipped, in the vast majority of cases this relationship is convex (McCann, 2001). Such transportation costs functions in which the delivered price is concave with respect to distance, and the transport rate per tonne-kilometre is convex with respect to both the haulage distance and haulage weight, are actually the natural (envelope) outcome of the inventory-shipment-frequency optimization problems faced by all hauliers (McCann, 2001).

It is important to be aware of this because when comparisons are made between the insights and predictions of spatial economic models incorporating iceberg transport costs with those which employ other more traditional transport costs functions, it must not be underestimated how fundamentally different are the notions of geography between these different types of systems. While it is clear that new economic geography models incorporating iceberg transport costs have gone further than any other framework in developing a general equilibrium approach to analysing spatial economic phenomena, at the same time, an awareness of limitations of the basic iceberg assumption require a certain caution when considering the geographical insights of these models.

5. A broad definition of distance costs

Any theoretical formulation of transport costs which is employed in a spatial model will always be rather incomplete, and therefore somewhat open to debate and questioning. Yet, the instrumentalist (Blaug, 1992) justification for the inclusion of any assumption in any particular model with any particular specification is to allow the overall model-system to provide additional insights into reality or for further model-building, and this is where the tractability issue (Krugman, 1998) discussed at the beginning of the paper becomes central.

As always, however, in moving from pure theory to interpretations and inferences of empirical and observational reality, it is necessary to take some additional steps or make some additional assumptions.[5] In this respect, one of the important features of the iceberg model is that the incorporation of the iceberg assumption within a CES framework leads to a trade specification which is structurally consistent with a gravity model specification (Brocker, 2002). Therefore, given that the observed structure of the iceberg model is generally inconsistent with observed estimates of transport rates structures, in order to link the theoretical new economic geography models with gravity model empirical approaches, it is necessary to make some additional assumptions. Proponents of new economic geography models therefore interpret the iceberg model as incorporating all forms of distance-transactions and trade costs, including information costs, institutional barriers, tariff barriers, quality standards and cultural and linguistic differences (Ottaviano, 1999, 3; Ottaviano and Thisse, 1999, 3) as well as simply transport costs (Fujita et al., 1999a, 97–98).

Although many of these distance-related costs are not observable directly, it is important to recognize that for this approach to hold, the implicit assumption here is that when all of these various distance costs issues are grouped together, the resulting distance costs function will be convex with distance, because it is this property which allows a move from a Samuelsonian iceberg-delivered price relationship (discussed in section 2) to something akin to a gravity model specification, which can then be tested and interpreted with respect to a new economic geography model.

However, there are three reasons why caution is needed when interpreting the use of these additional assumptions and this approach. Firstly, the gravity and entropy based framework (Wilson, 1970, 1974) is consistent with a whole range of different types of

5 In theoretical models, space is usually assumed to be homogenous, such that a distance measure D is the viewed as being same for movements in all directions and from all locations. However, in reality, space can be very non-homogeneous. Therefore, in moving from pure theory to empirical reality, the nuances of the real-world context must also inform our inferences from any type of spatial models.

distance costs functions and theoretical models (Sen and Smith, 1995) both prior to, and subsequent to the advent of new economic geography. This is because spatial interaction models are inherently probabilistic in nature, and are not dependent on particular assumptions about spatial pricing.

On the other hand, the gravity model logic embedded in the Krugman iceberg function is an explicit assumption. In new economic geography models, the consumption patterns at any location L are determined by the costs of goods production at L and also the delivered prices of goods produced at any alternative location M within the location space set S, where L,M S. The assumption of the convex-with-distance iceberg delivered prices is required in order to generate a gravity model-type structure. Therefore the gravity model cannot be an independent test of the iceberg assumption. Moreover, although gravity models tell us that geographical distance does matter in terms of determining the volume of trade, gravity models themselves do not reveal whether the impact of geography on trade flows is primarily via the impact of geography on trade costs or on the impact of trade costs on trade volumes (Overman et al., 2001). Therefore, while the gravity model can be regarded as being consistent with the Krugman iceberg function, it is not in any way a justification or validation of it.[6]

It can also be shown that similar problems are faced when using analyses of the relationship between the delivered and origin prices of internationally traded goods Brakman et al. (2001, 81–83), or more sophisticated gravity-type composite estimates which combine information on both the volumes and the values of trade (Overman et al., 2001). As Neary (2001, 54) points out, the various empirical work based on gravity flows does not provide an independent test of the new economic geography system as against any of the other plausible alternatives. As such, gravity models cannot be an independent test of the iceberg model over any other types of distance costs functions with different properties.

Secondly, the empirical evidence on the relationship between geographical distance and information access costs or information transfer costs, does not point to anything which is suggestive of an iceberg type convex distance-costs structure. Although there is much evidence on certain aspects of information localization (Acs, 2002; Gaspar and Glaeser, 1998) within cities,[7] there is also much evidence to suggest that the relationship between geographical distance and information transactions costs usually exhibits significant economies of distance (Cohen, 1998; Leyshon and Thrift, 1997). For both the geographical transfer of services as well as manufactured goods there is as yet no empirical evidence whatsoever which supports a convex distance-costs relationship, whereas there is a large body of evidence which points to widespread economies of distance.

6 To adopt a full Wilsonian spatial interaction perspective within a regional system would actually require that, as well as the flows of goods and services, the labour migration adjustment mechanism in the model would also exhibit a gravity type relationship (Fotheringham, 1991). This is not done in NEG models, and in this sense the gravity type interactions are somewhat selective.

7 Following Marshall's (1920, 271) often-quoted comment that the 'mysteries of the trade become no mysteries; but are as it were in the air'. These mysteries of the trade are viewed in more modern terms as representing localised information and knowledge externalities. Interestingly, Marshall was not the first observer of these phenomena, not did he originate the term 'district' in this context, and nor was he the first to identify information and knowledge linkages, the availability specialist local input sources, and also skilled labour inputs as the key features of such districts. A detailed analysis of each these issues was first provided in the context of a 'manufacturing district' by the *British Parliamentary Papers* (1845) Vol.39, Paper No: 2215, pp 311–313, as part of the enquiry into the extension of the railway system of Manchester, over forty years before Marshall's initial comments on these matters.

Thirdly, there is no economic or statistical reason why the total tariffs payable on the geographical movements of goods or services, as the goods move across successive borders, should systematically exhibit a convex distance price relationship.[8] The reason for this is that local border tariffs are never set according to the distance travelled of the goods. Even if by chance international tariffs exhibited a convex distance-costs structure, these tariffs would have to be so enormous as to dominate the structure of transportation costs. Tariff barriers are generally not of this order of magnitude. Moreover, even if this were so, then there would always be a market opportunity to break up shipments into multiple short shipments in order to avoid these tariffs. The result of this is that the application of such tariffs across space often makes distance cost functions even more concave with distance than transport costs alone (Jansson and Shneerson).

Commenting on this argument that the iceberg assumption reflects a broad definition of distance-trade costs, Neary (2001, 551) points out that in a field such as new economic geography which emphasizes the role of increasing returns to scale '... of all industries it (transportation) seems to be characterised by high ratios of fixed to variable costs ... This is particularly important if transport costs are interpreted broadly to include the communications and other costs associated with trade, which are likely to exhibit network externalities'.

When we consider the logic of tariffs as well as the available evidence on information transactions costs, in addition to transport-movement costs, we could quite easily argue that a broad definition of transport costs will actually be more likely to produce delivered price structures which are concave with distance rather than one which is convex with distance. Therefore, the argument that iceberg costs, and the distance-costs properties inherent in the iceberg costs model, represent a much broader definition of distance costs than simply transport costs, also becomes very doubtful indeed.

6. Conclusions

The argument presented here relates only to the case of fundamentally spatial versions of new economic geography models in which distance is an explicit variable. In the case of these types of models, irrespective of whether they are of a one-dimensional (Krugman, 1991, 1993; Fujita and Krugman, 1995; Fujita and Mori, 1996, 1997; Fujita et al., 1999a, 1999b) or a two-dimensional nature (Stelder, 2002), it is necessary for us to be rather cautious about how we interpret the theoretical insights of these papers when moving from theory to reality or from theory to policy analysis. The reason for this is that such papers are based on an iceberg transport costs specification which is largely implausible (Krugman, 1998, 165).

The properties of the Krugman iceberg model, which are quite different to the Samuelson iceberg model, imply that the delivered prices of goods increase exponentially with the distance shipped. On the other hand, all of the available evidence suggests that delivered prices tend to be concave rather than convex with

8 In order for this to be so, successive tariffs should get larger as the distance from the origin A increases. However, this there is no reason why this should be so as local border tariffs are never set according to the distance travelled of the goods, but rather according to the value or weight of the shipment. Moreover, if the tariff barriers involved in trade movements from A to B happened by chance to exhibit a convex distance costs structure, then trade movements from B to A will be concave with distance.

distance. As such, the treatment of geography and space in these types of new economic geography models is very particular, and is based on assumptions which would be regarded as untenable in most other spatial models.

Where attempts are made to justify the iceberg assumption with recourse to observation, it becomes clear that these justifications are very weak. Although gravity models may initially appear to provide some empirical support to the iceberg assumption, they are not an independent test of these new economic geography models, as against any alternative schema. Moreover, the argument that the iceberg model represents a broad definition of distance costs also appears to be very weak indeed.

Exactly how problematic this iceberg assumption is probably depends on one's point of view, as the empirical evaluation of this would not appear possible. On one hand, we could argue that from the perspective of economic geographers or transportation scientists, the iceberg assumption is probably the weakest aspect of new economic geography models. The reason for this is that it is this particular assumption, and this assumption alone, which allows for a movement from new trade theory to explicitly spatial versions of new economic geography, at least as they currently stand.[9]

On the other hand, for analysts focussing on issues of industrial organization, the treatment of firm dynamics in new economic geography may be considered to be more problematic (Neary, 2001, 548–550), although other observers do not regard these as particularly problematic, arguing that that this is a reasonable approximation of what could be obtained in a general equilibrium model with strategic interactions (Ottaviano and Thisse, 2003, 30).

Notwithstanding the criticisms regarding the limitations of the model assumptions, however, as we have already pointed out, it is clear that new economic geography models have gone further than any other framework in developing a general equilibrium approach to analysing spatial economic phenomena (Isard, 1999) and that a new and distinct research programme (Lakatos, 1970) has been established. However, the problems of the iceberg assumption imply that even if we were to adopt a broadly instrumentalist perspective (Blaug, 1992) in our interpretation of new economic geography models, what is not yet clear is how generalizable are these new economic geography insights to the real world. Therefore, following a Lakatosian approach, an awareness of limitations of the basic iceberg assumption should still lead us to be rather cautious when considering the geographical insights of these models, particularly in the light of empirical work or other theoretical models.

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9 For example, from the perspective of the future developments of economic geography modelling and analysis, Isard (1999, 383–384) argues that the '... first advance would involve dropping the iceberg assumption regarding transport costs ...' because actual transport rates contrast sharply with the iceberg formula. Therefore, it would be necessary '... to discard this notion (essentially a trick from mathematics) in ... an effort at evolving models for applied research. There are major indivisibilities and both increasing and decreasing returns in transportation activity in reality, which then affect the nature of increasing and decreasing returns in other activity. Ignoring these indivisibilities is ignoring a basic aspect of space as it realistically impinges upon activity.'

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