Trade and Geography:
Paul Krugman and the 2008 Nobel Prize in Economics

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January 2009

1.   Introduction

By announcing on October 13th 2008 to award the 2008 Nobel prize in economics to Paul Krugman, two (sub-)disciplines in economics were singled out for praise according to the prize committee of the *Royal Swedish Academy of Sciences* in their scientific background report (p.1): "*Traditionally, trade theory and economic geography evolved as separate subfields of economics. More recently, however, they have converged [to] become more and more united through new theoretical insights, which emphasize that the same basic forces simultaneously determine specialization across countries for a given international distribution of factors of production (trade theory) and the long-run location of those factors across countries (economic geography)*."[2] The committee stresses that the award was essentially given to Krugman for three of his papers: Krugman (1979, 1980, 1991). The first two papers are about international trade, notably intra-industry trade, whereas the last paper extends the analysis by endogenizing the spatial allocation of economic activity, making it the core model of the new economic geography literature.

It is not the first time that both international trade theory and economic geography are mentioned together by the Nobel prize committee. More than thirty years ago, the press release that announced that the 1977 Nobel prize was awarded to Bertil Ohlin (joint with James Meade), stated that "Ohlin … demonstrated similarities and differences between interregional (intra-national) and international trade, and the connection between international trade and the location of industries (Nobel prize committee press release, 1977, p. 1)." Ohlin's work did not go unnoticed to Krugman. On the contrary, in Krugman (1999) he includes the following quotation from Ohlin (1933) to sum up the connection between his own and Ohlin's views with respect to the relationship between (international) trade and (economic) geography: *"[T]he advantages of producing a large quantity of a single commodity instead of a little of all commodities must lead to interregional trade ... insofar as the market for some articles within each region is not large enough to permit the most efficient scale of production, division of trade and labor will be profitable. Each region will specialize on some of these articles and exchange them for the rest ... The tendency toward specialization*

because of differences in factor endowments is reinforced by the advantages of large-scale production. The location of an industry in one region and not in another might simply be due to chance ... Thus, all interregional trade, whether due to the one cause or the other, might be regarded as a substitute for geographical mobility of productive factors." (Ohlin (1933 as cited in Krugman, 1999) Readers who are familiar with Krugman (1991), the core model of the new economic geography literature, will no doubt recognize the similarity with Krugman's own work.

If it were not for the combination of the disciplines of trade and geography into a single consistent framework, Krugman might have had to share his prize with, for example, Elahanan Helpman or Avinash Dixit, if it had been based purely on his work on trade theory, or maybe with Masahisa Fujita, Tony Venables or Jacques Thisse, if only geography or spatial economics had counted. It is indeed the combination of his contribution to both trade and geography that makes Krugman's work special. In this paper we will dissect and highlight the sequence of steps in the three papers that basically got Krugman the 2008 Nobel prize in economics. In doing so, we will not only discuss the importance of each of these three contributions but we will also show how these three papers can essentially be looked upon as the sequential development of a single underlying model. Three features stand out. First, Krugman (1979) analyzes what happens in an economy that is characterized by increasing returns to scale and imperfect competition if countries start to trade. Second, in Krugman (1980) transport costs are introduced and basically added to the increasing returns framework of the 1979 paper. This addition gives rise to the so-called home market effect, which then forms the starting point and backbone of Krugman (1991). Third, in Krugman (1991) the combination of the home-market effect with interregional labour mobility endogenizes the location decisions of not only firms but also of footloose workers and hence, unlike his 1980 model, endogenizes the spatial allocation of both supply and demand, and this may give rise to center-periphery equilibria.

After our discussion of the three award winning papers in sections 2-4 respectively, we will briefly evaluate Krugman's contributions in section 5 which will conclude our appraisal of the work underlying the 2008 Nobel prize in economics. Our paper is explicitly neither a survey of (new) trade theory nor a survey of (new) economic geography. We will focus on the three aforementioned papers and deliberately neglect other contributions by either Krugman or his

fellow researchers.[3] In essence, by discussing the 1979, 1980 and 1991 papers at some length we will illustrates why the Nobel prize 2008 for Paul Krugman was in our view well deserved (see also Fujita and Thisse, 2008).

2. The Krugman (1979) model: increasing returns and intra-industry trade

As explained and nicely summed up by Krugman himself in his Nobel lecture (see footnote 2), it had become increasingly clear during the 1970s that the standard workhorse models of international trade were at odds with the facts. The standard models, notably the Heckscher-Ohlin and the Ricardian model and their focus on a country's comparative advantage, gave a rationale for inter-industry trade only. But empirical research (Grubel and Lloyd, 1975) clearly showed that trade between (developed) countries was mainly in the form of intra-industry trade. The bulk of trade was trade in similar goods between similar countries, something which was contrary to the existing trade models. The challenge was thus to come up with a trade model that explained and allowed for intra-industry trade. This was indeed a challenge because it was clear that the explanation should centre on the role of increasing returns to scale and on an imperfect competition market structure. Krugman (1979) was the first to succeed in meeting this challenge.

Krugman (1979) uses a simplified version of the monopolistic competition model as developed by Dixit and Stiglitz (1977). This Dixit-Stiglitz model provides a fruitful way to model monopolistic competition. Almost overnight it became the preferred choice of researchers to model monopolistic competition, and it has become the benchmark model in various fields (see Brakman and Heijdra, 2004). Krugman (1979) introduced the basic model to the field of international trade; we give the nuts and bolts of the model below.

Demand

Intra-industry trade involves the consumption of closely related goods. Cars from Germany can for example be exchanged for cars from France. In Krugman (1979), household utility is characterized by a love-of-variety effect that assumes that each variety, $i = 1..n$, of a commodity enters utility symmetrically as an incomplete substitute:

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[3] For extensive surveys or introductions to new trade trade theory see for instance Feenstra (2004), Helpman and Krugman (1985), or Bhagwati et al (1998). For surveys and introduction on new economic geography and in particular on the Krugman (1991) model see Fujita. Krugman, and Venables (1999), Neary (2001), Baldwin et al (2003, ch. 1), Combes, Mayer and Thisse (2008), Brakman, Garretsen and van Marrewijk (2009), Ottaviano and Thisse (2004) or Head and Mayer (2004).

(1) $U = \sum_{i=1}^{n} v(c_i)$, where $v' > 0, v'' < 0$

The elasticity of demand is:

(2) $\varepsilon_i = -\dfrac{v'}{v'' c_i}$, with $\partial \varepsilon_i / \partial c_i < 0$

It is important to note that the elasticity is not constant but declining in consumption, c_i. As we will see below, this has implications for the way the presence of increasing returns to scale affects the economy.

Supply

Crucial for all the results in Krugman (1979) as well for those in Krugman (1980, 1991) is the market structure of imperfect competition. For the explanation of intra-industry trade, it is necessary that closely related goods are produced in different places. If this is the case, intra-industry trade follows immediately in a two country model if each variety is consumed by all consumers. A simple way to introduce (internal) economies of scale and to ensure that each variety i is produced by a single firm is via the following labor cost function:

(3) $l_i = \alpha + \beta x_i$, where $\alpha, \beta > 0$

Labor, l_i, is the only production factor, which earns a wage w. The parameters α, and β are the fixed and marginal costs respectively (the fixed costs give rise to the internal scale economies). Equation (3) implies that average costs are decreasing in the quantity of variety i that is produced. This ensures that in the competitive equilibrium a particular variety is produced by the firm that had initially the largest market share and thus the lowest costs per unit of production.

The full-employment condition describes that the summation of equation (3) over all varieties equals total labor supply:

(4) $L = \sum_{i=1}^{n} l_i = \sum_{i=1}^{n} \alpha + \beta x_i$

Firms are defined symmetrically which implies that $p_i = p; x_i = x$ for all i.

Equilibrium

The next step is to derive the market equilibrium. This gives the equilibrium output of each firm, x_i, the equilibrium number of varieties and hence the equilibrium number of firms, n, and it also yields the equilibrium price wage ratio, p_i/w_i. Consumers maximize equation (1) subject to the individual income constraint which gives:

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(5) $\qquad p_i = \lambda^{-1} v'(c_i) = \lambda^{-1} v'(x_i/L),$

where λ^{-1} is the inverse of the associated marginal utility of income.

In general, the marginal utility of income is a function of all prices and of the individual's income. Firms are too small to affect the marginal utility of income if we assume that there are many firms. So, an individual firm's change in its pricing policy will not affect the marginal utility of income. Equation (5) is the inverse demand function for a firm producing x_i, from which we can derive the elasticity of demand that faces each firm as:

$$\varepsilon_i = -\frac{p_i}{c_i}\frac{dc_i}{dp_i} = -\frac{v'}{v'' c_i}$$

With this expression for the elasticity of demand we derive the familiar mark-up pricing rule from equating marginal costs to marginal revenue (dropping the index because of symmetry):

(6) $\qquad p = \dfrac{\varepsilon}{\varepsilon - 1} w,$ or $p/w = \dfrac{\varepsilon}{\varepsilon - 1}\beta,$

Note that because of equation (2) the mark-up increases with an increase in c.

The zero profit condition implies that:

(7) $0 = px - (\alpha + \beta x)w \Rightarrow p/w = \beta + \alpha/x = \beta + \alpha/Lc,$

Equations (6) and (7) together give the breakeven output, $x,$ of a firm that is consistent with profit maximization, and free entry and exit into the market: $x = \dfrac{(\varepsilon - 1)\alpha}{\beta}.$

It is now useful and instructive to combine mark-up pricing equation (6) and the zero profit equation (7) into a single figure.

Figure 1 shows the mark-up on the vertical axis and consumption of a variety on the horizontal axis. The PP line depicts equation (6) and the ZZ line depicts the zero profit condition, equation (7).

Figure 1 The Market Equilibrium
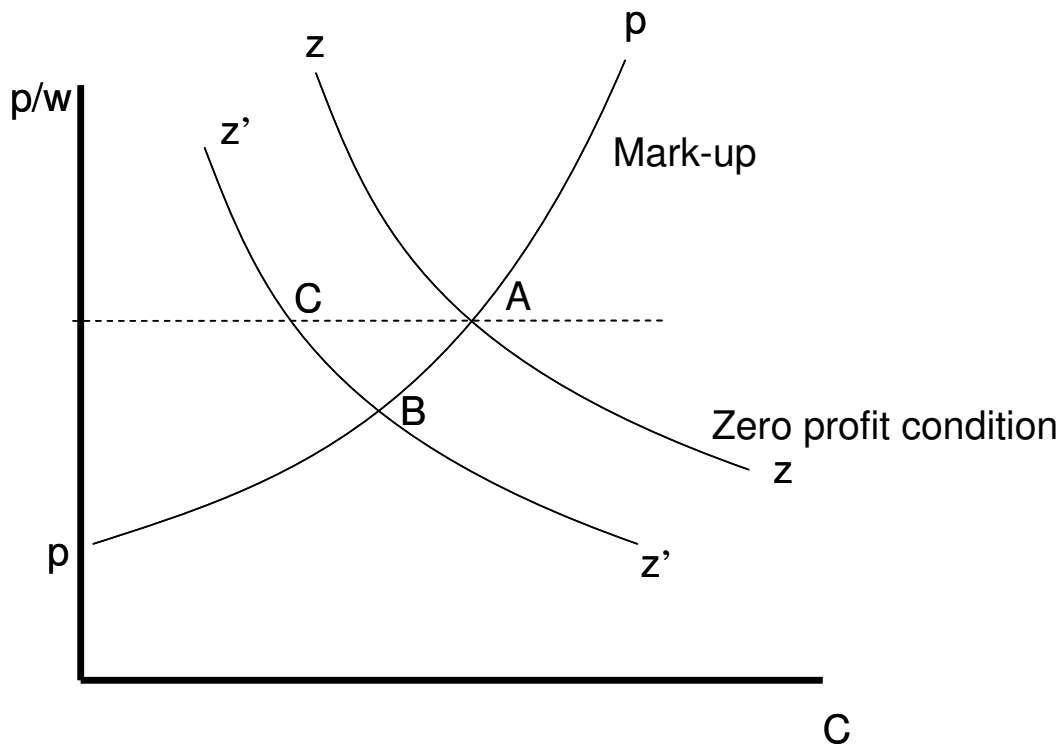
What can we learn from Figure 1? First consider point A. The intersection of the ZZ curve and the PP curves determines the per capita consumption of each good. All consumers consume each good so $Lc = x$. Furthermore we have

$$(8) \qquad n = L \Big/ l_i = \frac{L}{\alpha + \beta Lc},$$

which determines the number of firms.

International trade

The description of the model so far only gives the equilibrium for a closed economy. Trade can now, however, easily introduced. First recall that in a standard Heckscher-Ohlin type of trade model two identical countries would never trade. In the monopolistic competition model, identical countries do trade. The reasoning is as follows. Introducing a second country is just like an increase in the labor supply: for two identical countries, for instance, a doubling of L. Inspecting equations (6) and (7) shows that an increase in labor supply affects only the position of ZZ, which shifts down as shown in Figure 1.

The gains of international trade now consist of three elements. First, the total number of varieties available to consumers increases (see equation (8)). The statement is immediately clear by dividing by *L*. But it is important to note that it is not clear which variety will be produced where. Firms are identical and according to the model no predictions can be made where a particular variety is produced. There is simply nor role for space or geography (yet). Second, the reduction in sales per variety increases the elasticity (see equation (2)) which reduces the mark-up, and thus increases the real wage. To see the third effect of trade, we start with the observation that the total number of varieties available to consumers increases. But what happens to the number of varieties produced *in each separate country*? From equation (7) we see that the decline in *p/w* (real wage increase) must be matched by an increase in output per firm, *Lc*. This, in essence, is a reflection of economies of scale. International trade allows countries to make better use of resources. It implies that for each country, compared to autarky, fewer varieties will be produced by a country and hence fewer firms will exist in a single country when trade is opened up.

The Krugman (1979) model soon became the dominant model to explain of intra-industry trade and has become the standard micro-foundation of this type of trade to be used by fellow reseachers and in textbooks. But despite its success and ability to explain why intra-industry trade can take place, one rather problematic feature of the model is that it remains silent where production and trade takes place. This is remedied in Krugman (1980).

3.   Krugman (1980): increasing returns and transport costs

Krugman (1980) adds transport costs to this basic model from the previous section, and this has far reaching implications. Even though the set up is similar to Krugman (1979), the demand structure is simplified: in equation (1) $v(c_i)$ is replaced by a constant elasticity of demand type of utility.[4] As a consequence the mark-up is also constant which implies that the gains of trade are still present but only in a more rudimentary way. We can see this by looking again at Figure 1 and by repeating the thought experiment of introducing a second country. From equation (6) it is obvious that the PP curve in Figure (1) in the case of constant elasticity of demand becomes a horizontal line, for expositional purposes indicated by the line AC in Figure 1. An increase in the available labor supply still shifts the average cost

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[4] The specific form Krugman (1980) chooses is c_i^{θ}

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curve to the left. This shift has implications for the number of varieties that are produced, which increases (see again equation (8)), but no longer impact on real wages or the number of varieties in each separate country (which remains the same as before international trade is allowed– see equation (7)). From the three sources of the gains of trade – as analyzed in the previous section – only one remains; the total variety effect. Consumers gain from trade because they consume more varieties than before international trade was allowed.

So far Krugman (1980) offers nothing spectacular, merely a simplication of Krugman (1979) in fact, but the big step forward concerns the introduction of transport costs. In Krugman (1980) it is assumed that the trade of varieties goes along with positive transport costs. As we will see below, the combination of increasing returns to scale (IRS) and transport costs implies that firms not only want to produce from a single location (because of IRS) but they now also care where they locate their production (because of the transport costs). Firms prefer to locate where demand for the variety they produce is relatively large. This interplay between IRS, transport costs and demand has become known as the home market effect. For didactical reasons and to be able to illustrate the continuity between Krugman (1980) and Krugman (1991), we will give a slightly different presentation of the home market (HM) effect than is offered in Krugman (1980).[5] Our discussion of the HM effect is in two parts: the more than proportional production of the increasing returns sector in the larger market (the volume effect, section 3.1), and the higher wages of the increasing returns sector in the larger market (the price effect, section 3.2). The key issue is that with positive transport costs, the larger market offers location benefits that are absent in models, like Krugman (1979), that do not include transport costs.

3.1 The Home Market effect: the volume effect

We concentrate on the location of economic activity in the larger market. Suppose we have two sectors in the economy. One sector produces a homogeneous good under constant returns to scale and the other sector is a differentiated IRS sector modeled as in Krugman (1979) along the lines of section 2. Utility maximization now consists of two stages. In the first stage of utility maximization, income is shared between both sectors (using a Cobb-Douglas utility

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[5] Our discussion of the HM effect is based on Helpman and Krugman (1985) and is consistent with Krugman (1991). Krugman (1980) derives the Home Market effect by using the balance of payment equilibrium as the key equation.

function). A share δ of total income goes to the differentiated sector, and $(1-\delta)$ to the homogeneous good. In the second stage utility for the differentiated sector is of the CES type:

$$(9) \qquad U = \left(\sum_{i=1}^{n} c_i^{\rho} \right)^{1/\rho} \text{ with } \rho = (1 - \frac{1}{\varepsilon})$$

If the number of varieties is (very) large, firms consider ε *(> 1)*, the elasticity of demand, as given. Utility maximization of equation (9) subject to the budget constraint of the second stage of utility maximization now gives[6]:

$$(10) \quad c_i = \frac{p_i^{-\varepsilon} \delta wL}{\sum_{j}^{n} p_j^{1-\varepsilon}}$$

The term in the denominator is related to the price index. In what follows, as above, we assume that there is only one factor of production, labor, that earns a wage w.

Transport costs

In Krugman (1980), the transport costs are of the iceberg type.[7] Iceberg transportation costs have the advantage that transportation costs can be introduced without having to deal with a transportation sector. Assume the iceberg costs are τ; that is τ units have to be shipped in order for one unit to arrive. This raises the costs of imported varieties to $p\tau$. Demand for a domestic variety now comes from two sources: domestic demand (11a) and foreign demand (11b). From (10) it is obvious that these two expressions are (where * indicates foreign variables):

$$(11a) \quad x_i = \frac{p^{-\varepsilon}}{np^{1-\varepsilon} + n^* (\tau p)^{1-\varepsilon}} \delta wL$$

$$(11b) \quad x_i^* = \frac{(\tau p)^{-\varepsilon}}{n(\tau p)^{1-\varepsilon} + n^* (p)^{1-\varepsilon}} \delta w^* L^*$$

Similar equations can be derived for the foreign country. From the discussion following equations (6) and (7) we know that output per firm is fixed and equal to x in equilibrium. Goods market clearing in each country for the increasing returns sector gives, for the home country:

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[6] For a step by step derivation of this two stage maximization problem, see for instance Brakman, Garretsen, and Van Marrewijk (2009, chapter 3).
[7] For a critique of the iceberg depiction of transport costs, see Fingleton and McCann (2007).

(12a) $X \equiv nx = \dfrac{np^{-\varepsilon}}{np^{1-\varepsilon} + n^*(\tau p)^{1-\varepsilon}} \delta wL + \dfrac{n(\tau p)^{-\varepsilon}}{n(\tau p)^{1-\varepsilon} + n^*(p)^{1-\varepsilon}} \delta w^* L^* \tau$

and, for the foreign country:

(12b) $X^* \equiv n^* x = \dfrac{n^*(\tau p)^{-\varepsilon}}{n(p)^{1-\varepsilon} + n^*(\tau p)^{1-\varepsilon}} \delta wL\tau + \dfrac{n^* p^{-\varepsilon}}{n(\tau p)^{1-\varepsilon} + n^*(p)^{1-\varepsilon}} \delta w L^*$

Note the additional τ multiplication terms in both expressions. In (12a) part of the home exports to foreign melts during transportation, but it needs to be produced before it can melt, and similarly in (12b) for exports from Foreign to Home.

The home market effect and equilibrium

Given the market clearing conditions (12a) and (12b) and assuming first that there are no transport costs with respect to the homogeneous product and second, as is standard in international trade theory, that labor is mobile between sectors but *im*mobile between countries, we know that wages in the homogeneous sectors in both countries are identical, and because of perfect inter-sector labor mobility, also in the increasing returns sector. Equation (6) allows us to choose units such that *p = w = 1*.

This implies that we can simplify equations (12a,b) as follows (with $Z \equiv \tau^{1-\varepsilon}$)[8]:

(12a') $\dfrac{x}{\delta} = \dfrac{1}{n + n^* Z} L + \dfrac{Z}{nZ + n^*} L^*$

(12b') $\dfrac{x}{\delta} = \dfrac{Z}{n + n^* Z} L + \dfrac{1}{nZ + n^*} L^*$

We have two equations and two unknowns, *n* and *n**. In principle we have three possible cases – numbered 1 to 3 - complete specialization in one of the two countries (cases 1 and 2), or incomplete specialization (case 3):

1. $n = 0$, $n^* = \dfrac{\delta(L + L^*)}{x}$, from (12b')

2. $n = \dfrac{\delta(L + L^*)}{x}$, $n^* = 0$, from (12a')

3. $n = \dfrac{\delta}{(1 - Z)x}(L - ZL^*)$, $n^* = \dfrac{\delta}{(1 - Z)x}(L^* - ZL)$, from (12a', 12b')

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[8] In the new economic geography literature $\tau^{1-\varepsilon}$ is known as the free-ness of trade, see Baldwin et al (2003)

Concentrating on the home country we can distinguish between these three possibilities. If we introduce the following notation, $s_l = \dfrac{L}{L + L^*}$, $s_n = \dfrac{n}{n + n^*}$ where s_l is the labor share and s_n the share of varieties or firms in Home, we arrive at:

$$(13)\ s_n = \begin{cases} 0, & \text{for } s_L \leq \dfrac{Z}{1+Z} \\[2ex] (1-Z)^{-1}[(1+Z)s_L - Z], & \text{for, } \dfrac{Z}{1+Z} < s_L < \dfrac{1}{1+Z} \\[2ex] 1, & \text{for, } s_L \geq \dfrac{1}{1+Z} \end{cases}$$

The first entry in (13) follows from combining case 1 with case 3 (where specialization of all increasing returns production in Foreign just becomes binding). Similarly, the last entry follows from combining cases 2 and 3. Finally, the middle entry follows from solving case number 3. The implications become clear if we depict these three possible cases in Figure 2:

Figure 2. Home Market Effect; the volume effect
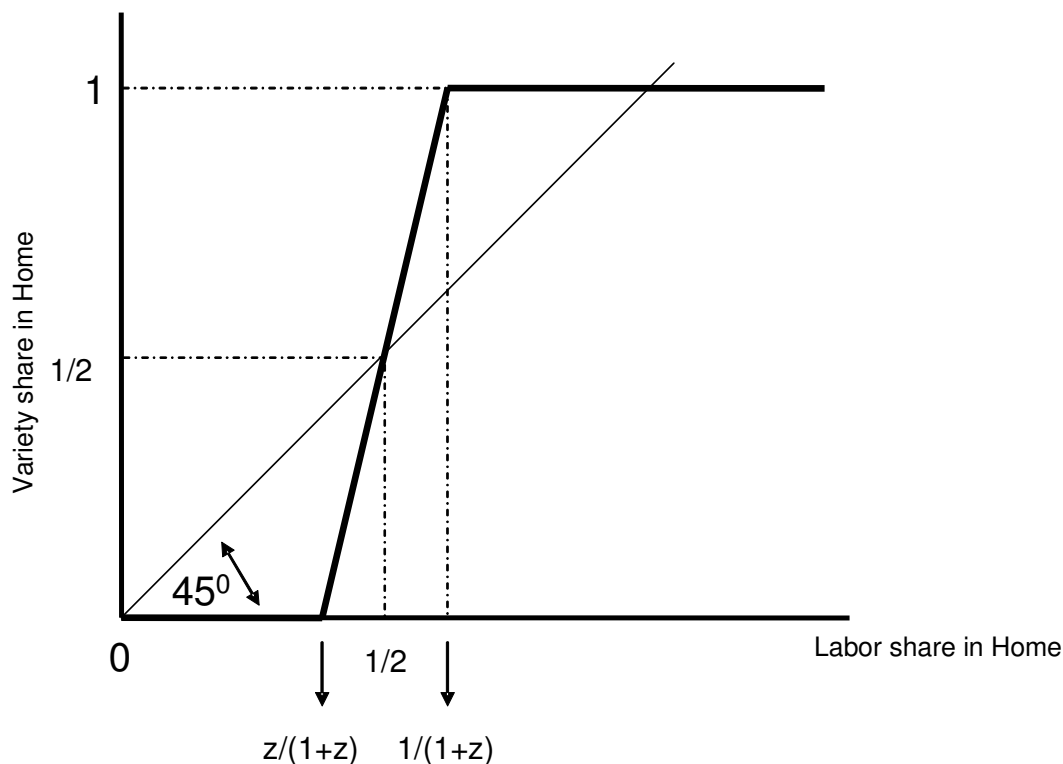
What we see is that if the Home country is large (small) enough in terms of labor relative to Foreign, it will attract (lose) all increasing returns manufactures. What is important in our

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discussion of the HM effect is the slope of the curve in the area $\frac{Z}{1+Z} < s_L < \frac{1}{1+Z}$. From

equation (13) we know that the slope of the line-piece is $(1-Z)^{-1}[(1+Z) > 1$, which implies that the larger country in this area has a *more than proportional* share of varieties and hence firms compared to its share in labor. The reasoning is as follows. Suppose that from the point *(½,½)* a foreign firm (together with its workers) relocates to the home country that now becomes the larger market (the reason why might take place is unimportant). This increases the market by the amount of workers that move, but it also increases the spending power of existing consumers who no longer have to incur transport costs resulting from importing the variety. This 'double' increase in demand raises profits in the larger market, and attracts more firms to the increasing returns sector. Points on the solid line indicate that the increase in the number of firms must be more than proportional than the number of workers (some workers come from the homogeneous sector) in order to restore equilibrium.

Why don't all firms have to move to the larger market in order to restore equilibrium? The reason is that additional firms also introduce more competition that reduces the (potential) profits in the larger market. To explore the thought experiment of making the home market larger, it is instructive to look at the denominator of equation (11a). A firm moving from Foreign to Home makes the denominator smaller (as the variety no longer has to be imported), and this implies more local competition. This competition effect is stronger, the higher are transport costs (high transport costs shield a market from foreign competition). So fewer firms have to move to re-establish equilibrium following to movement of a firm from Foreign to Home if transport costs are high (the slope of the line gets closer to the 45^0 line).

3.2   Beyond the simple home market effect……..
To sum up, by combining IRS and transport costs in the basic model of Krugman (1979), Krugman (1980) was able to show that a country with larger market (in Figure 2, the country with a relatively large share of workers) is able to attract a more than proportional share of firms or varieties. Or in other words, countries or regions with a relative large demand for a good are home to a more than proportional share of production of that good. Against this home market or market size effect, the competition effect acts to ensure that in equilibrium, and depending on the model's parameters (notably on the level of Z), not all firms in the differentiated IRS sector need to end up choosing the larger market as their location. From an empirical point of view, the Krugman (1980) model does give rise to a testable hypothesis

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with respect to international trade flows: countries with a relatively large home market for variety i ceteris paribus are net exporters of this variety. In the trade literature (see e.g. Davis and Weinstein 2003), this implication of the home market effect has been subjected to a battery of tests. Three other observations are relevant w.r.t. the home market effect. The first one is that the effect is quite sensitive to the underlying assumptions. If international trade in the homogenous good is also subject to transport costs, the home market effect ceases to exist (Davis, 1998). Also, the analysis of the home market effect quickly gets quite complicated (or even muddled) for the case of $n>2$ regions or countries (Behrens et al, 2005, Head and Mayer, 2004). The second observation is that in the example of Figure 2, a large home demand (here, a large s_L) leads to an influx of firms where the necessary labor to enable the additional production has to be released from the homogenous sector. Given that international labor mobility is possible, the additional demand for labor by the firms in the differentiated IRS sector in Home does indeed fully materialize in higher production because of an infinitely elastic intersector labor supply in Krugman (1980). If labor supply is not perfectly elastic at least part of the response to a larger market will be in the form of higher wages (Fujita. Krugman and Venables, 1999 eq. 4.42, Head and Mayer, 2006). As we will see next, with a less than elastic labor supply, a relatively large demand or a larger home market then translates (partly) into higher wages. A third and final observation is that in Krugman (1980) the distribution of demand across locations is given. This is a direct consequence of the fact that workers and hence consumers are immobile between locations. Any demand or market size differences are therefore exogenously given. But what if one drops this assumption? What if not only (IRS) firms but also (some) workers are mobile and can choose in which country or location they wish to locate? Answering this question leads us directly from Krugman (1980) to Krugman (1991) but only after we give another manifestation of home market effect in terms of a factor price effect, instead of the volume version discussed above.

The home market effect becomes a factor price effect

In the example underlying Figure 2 we, by construction, ignored any effect that market or demand size differences might have on wages. Labor was perfectly elastic between sectors but not between countries, which is the usual assumption in international trade theory. This enables us to focus on the number of varieties (firms). In Krugman (1991) an opposing case is introduced; the larger market does not attract more than a proportional share of firms, compared to its share in labor, but all benefits of a larger market now show up in higher wages in the increasing returns sector.

Actually such a wage effect can already be seen as an outcome of the Krugman (1980) model, we only have to change one assumption: labor is not only immobile between countries, but now also immobile between sectors. The implications are that we no longer have factor price equalization and that the number of varieties (firms) is proportional to the given quantity of labour in the increasing returns sector (so by assumption the HM effect of the previous section is absent). The set-up of the model remains the same, but we can no longer take the steps to simplify (12a) and (12b) to (12a') and (12b'). At the same time it is true that location in the larger market offers benefits relative to location in the smaller market. Again, as in the previous section, location in the larger market implies that firms do not have to incur transport costs and that this increases the spending (real income) of consumers. How does it show up in this case? We can use equation (12a) to show this for the Home country (and similarly for the Foreign country using equation 12b). Note, that as wages are not necessarily the same, prices also differ between countries. Furthermore, we have to be careful how to define income, Y and Y^*, in this case, see below. Taking care of these aspects results in:

$$(14) \quad \frac{(\varepsilon-1)\alpha}{\beta} = \frac{np^{-\varepsilon}}{np^{1-\varepsilon} + n^*(\tau p^*)^{1-\varepsilon}} \delta Y + \frac{n(\tau p)^{-\varepsilon}}{n(\tau p)^{1-\varepsilon} + n^*(p^*)^{1-\varepsilon}} \delta Y^* \tau$$

Where we use the fact that mark-up pricing together with the zero profit condition fixes the break even point of firms (see discussion following equations (6) and (7)). Using $p = \frac{\varepsilon}{\varepsilon-1} w$,

and $p^* = \frac{\varepsilon}{\varepsilon-1} w^*$, we can rewrite equation (14) in terms of wages in the manufacturing sector (and do the same for the foreign country):

$$(15a) \quad w = \rho\beta^{-\rho} \left(\frac{\delta}{(\varepsilon-1)\alpha}\right)^{1/\varepsilon} \left(YP_1^{\varepsilon-1} + \tau^{(1-\varepsilon)} Y^* P_2^{\varepsilon-1}\right)^{1/\varepsilon}$$

$$(15b) \quad w^* = \rho\beta^{-\rho} \left(\frac{\delta}{(\varepsilon-1)\alpha}\right)^{1/\varepsilon} \left(Y^* P_2^{\varepsilon-1} + \tau^{(1-\varepsilon)} Y \ P_1^{\varepsilon-1}\right)^{1/\varepsilon}$$

where $P_1^{1-\varepsilon} = n(w/\rho)^{1-\varepsilon} + n^*(\tau w^*/\rho)^{1-\varepsilon}$, $P_2^{1-\varepsilon} = n(\tau w/\rho)^{1-\varepsilon} + n^*(w^*/\rho)^{1-\varepsilon}$

These equations make perfect sense. Wages in Home are larger if it has a large home market in terms of real income, YP_1, or if it is located near a large Foreign market (large $Y^* P_2$ and low transport costs, or equivalently a high free-ness of trade, $\tau^{1-\varepsilon}$). The benefits of a large

market are now not reflected in a more than proportional share of firms relative to the labor share, but in higher wages.

4.   Krugman (1991): IRS, transport costs and interregional labor mobility

The conclusion at this point is that transport costs change the Krugman (1979) model fundamentally. The Krugman (1980) model is about a different world than the Krugman (1979) model. In particular, geography or location matters in the former but not in the latter. The location choice becomes important for IRS firms because they want to minimize transport costs and thereby location in the larger market becomes attractive. But, as we stated above, the distribution of labor and hence of demand between locations is still given in Krugman (1980).

It took Krugman some time, 11 years to be precise[9], to realize that dropping the assumption of interregional labor immobility could be seen as the last step needed to come up with a full blown general equilibrium model of location choice where both the spatial distribution of supply (firms) and demand (workers) would be the determined endogenously by the model: "*Michael Porter had given me a manuscript copy of his book on Competitive Advantage of Nations, probably late 1989. I was much taken by the stuff on clusters, and started trying to make a model - I was on a lecture tour, I recall, and worked on it evenings, I started out with complicated models with intermediate goods and all that, but after a few days I realized that these weren't necessary ingredients, that my home market stuff basically provide the necessary. I got stumped for a while by the analytics, and tried numerical examples on a spreadsheet to figure them out. It all came together in a hotel in Honolulu.………*" (cited in Brakman, Garretsen and van Marrewijk, 2009**)**

With the benefit of hindsight, the way Krugman proceeded from his 1980 to his 1991 model was indeed quite straightforward.[10] With one notable exception, all the necessary ingredients were already present in Krugman (1980). The only thing to add is the possibility of interregional labor migration. This implies that a region's market size becomes endogenous when migration is allowed to take place (see also Ottaviano and Thisse, 2004 and Head and

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[9] Maybe it also took some time because the addition of interregional labor mobility to an otherwise basically unchanged Krugman (1980) model meant that the 1991 model could not be solved analytically but only via numerical simulations, and with the arrival of the PC and simulation software packages this was not much of a problem by 1991 as compared to the pre-PC days of 1980.

[10] Krugman (1991) proceeds by concentrating on sales. We follow Fujita, Krugman and Venables (1999) and their analysis which is also consistent with the model from Krugman (1979).

Mayer, 2004). In the 2 region setting of Krugman (1991) the equilibrium conditions of the model can be stated as follows:

(16a) $Y = wL + 0.5L_H$

(16b) $Y^* = w^* L^* + 0.5L_H$

(16c) $w = \rho \beta^{-\rho} \left(\dfrac{\delta}{(\varepsilon-1)\alpha} \right)^{1/\varepsilon} \left(Y P_1^{\varepsilon-1} + \tau^{(1-\varepsilon)} Y^* P_2^{\varepsilon-1} \right)^{1/\varepsilon}$

(16d) $w^* = \rho \beta^{-\rho} \left(\dfrac{\delta}{(\varepsilon-1)\alpha} \right)^{1/\varepsilon} \left(Y^* P_2^{\varepsilon-1} + \tau^{(1-\varepsilon)} Y \ P_1^{\varepsilon-1} \right)^{1/\varepsilon}$

(16e) $P_1^{1-\varepsilon} = n(w/\rho)^{1-\varepsilon} + n^*(\tau w^*/\rho)^{1-\varepsilon}$

(16f) $P_2^{1-\varepsilon} = n(\tau w/\rho)^{1-\varepsilon} + n^*(w^*/\rho)^{1-\varepsilon}$

(16g) $\omega = \dfrac{w}{P_1^\delta}$, $\omega^* = \dfrac{w^*}{P_2^\delta}$

(16h) $\dfrac{dL}{L} = -\dfrac{dL^*}{L^*} = \eta(\omega - \varpi)$, with $\varpi = \lambda w + \lambda^* w^*$

The model uses familiar ingredients, but also includes a few new aspects. Equations (16a) and (16b) are the income equations in the 2 regions or countries, Home and Foreign. The first term on the right hand side indicates income earned in the increasing returns sectors that earn wages w and w^* in Home and Foreign, respectively. We assume that labor (in the increasing returns sector) is mobile between countries but not between sectors. The distribution of labor in the homogeneous (agricultural) sector is given and does not change. Total labor supply in this sector is L_H, and we assume – just for simplicity - that it is equally distributed over the two countries. There are no transport costs in this sector implying that wages earned in the homogeneous goods sector are equal in the 2 regions, and we can use this sector as the numeraire sector, and wages in the increasing returns sector are relative to the wages in the homogeneous goods sector. It is important to note that we can not do without this homogeneous goods sector. It implies that even when labor in the increasing returns sector is completely agglomerated by being located in just one of the two regions, there is always a positive (residual) demand in the other region, and firms might want to re-locate to this region in order to get away from the stiffer competition in the larger region.

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Equations (16c)-(16f) are familiar from above. Equations (16g) and (16h) give the dynamics in the model and they represent the difference between Krugman (1991) and (1980). First, we define real income in equation (16g). It is simply wages divided by the price index of all the commodities consumed. As the increasing returns to scale sector comprises of a share δ in the consumption basket, we want to correct for this.[11] We also divide by the price in the homogeneous sector (raised to the power 1-δ, the share of the homogeneous goods sector), but this does not show up in the model because the homogeneous good is the numeraire good (and the price equals 1). Equation (16h) states that labour in the increasing returns sectors moves to the region with the highest real wage. Of course, in the real world migration decisions are based on much more than just real wages. The model easily gets quite complicated because if labor moves, to say, the Home country, this changes incomes (equations 16a, 16b), which affects nominal wages (equations 16c, and 16d), and also the prices indices (equations 16e, and 16f), which subsequently affect the migration decision itself, and given the functional forms of the model, these effects are non-linear.

In Krugman (1991) numerical simulations are used in order to find out what the spatial equilibrium will look like when the labor force in the IRS sector can migrate between the 2 regions. Transport costs turn out to be very important in determining what the spatial equilbrium allocation of firms and workers will look like. Given the key model parameters like the value of transport costs, the "tug of war" between the agglomeration forces (home market effect, price index effect) and the spreading forces (competition effect), see below, determines what the equilibrium spatial allocation will be. It turns out that the model has basically three (stable) equilibria: full agglomeration in Home or Foreign, and perfect spreading. In addition, the Krugman (1991) model is not only characterized by multiple equilibria but also by path dependency.[12] Figure 3 sums up the model. The so called Tomahawk depicted by Figure 3 shows that for low free-ness of trade $\tau^{1-\varepsilon}$ (=Z in the previous section), that is for high transport costs, footloose labour is evenly spread between the 2 regions but if the free-ness of trade gets high enough, that is if transport costs get low enough, all footloose workers end up in either region 1 or 2 in equilibrium.

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[11] Note, that P_1 and P_2 are price indices associated with the CES sub-utility indices, which explains the somewhat complicated notation of these expressions, see Brakman, Garretsen and Van Marrewijk (2009, chapter 3) for a detailed discussion of these price indices.

[12] Note that Figure 3 is a translation of Figure 3 in Krugman (1991) in terms of the share of the footloose labour instead as in terms of relative sales as in Krugman (1991).

Figure 3 The Tomahawk from the Krugman (1991) model
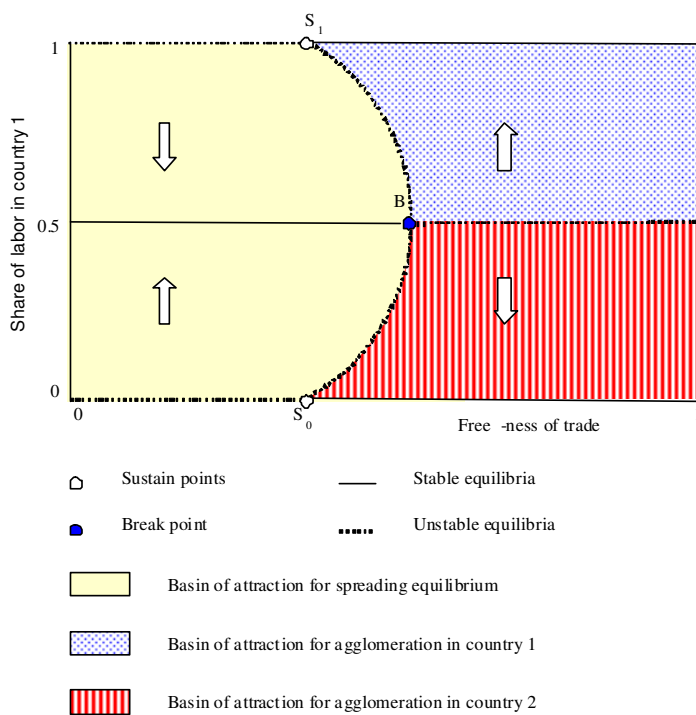
The solid lines indicate stable equilibria, the dashed lines indicate unstable equilibria. The arrows indicate in what direction the incentive for firms (and footloose labor) points, depending on the value of transportation costs.

What are the forces that determine interregional migration? Three forces matter in the Krugman (1991) model: the price index effect, the home market effect, and the extent of competition effect. The price index effect stimulates agglomeration in the larger market as fewer varieties have to be imported and this saves on transport costs. This effect is magnified by the home market effect discussed above. In the Krugman (1991) model, the home market effect results in higher wages (see section 3.2) and makes the larger market more attractive. These agglomeration effects are counteracted and diminished by the extent of the competition effect, which acts as the spreading force. If a firm moves to the larger market the denominators in (12a) and (12b) become smaller, which reduces the demand for an individual firm. The more firms (and workers) there are in a region, the higher the level of competition will be.

The balance between these three forces determines the direction of the arrows in Figure 3. For low values of transport costs (high values of the free-ness of trade) this competition effect is felt less as the price difference between markets become smaller. Note from Figure 3 that there is not a gradual change from one stable equilibrium to another, but instead a catastrophic change; the moment the balance tilts between these forces it is either full agglomeration or perfect spreading. Starting from an initial situation of a low free-ness of trade (left part of x-axis in Figure 3), the point at which this happens is the so called break point, B. Moving from high to low transportation costs, spreading is no longer a stable equilibrium (breaks) if transport costs are reduced further. One could also start with very low transport costs (high free-ness of trade) and then subsequently increase transport costs (lower the free-ness of trade) until agglomeration becomes unstable. This happens at the sustain points S in Figure 3.[13]

Answering Ohlin's call.

The real contribution of Krugman (1991) is that the location of both (IRS) firms and workers becomes endogenous and that Krugman was the first to do this is a fully specified general equilibrium framework (Fujita and Thisse, 2008). The model does not rely on any exogenous assumptions regarding the economic geography, possibly *a priori* favouring one location over another. This is a significant step forward with respect to existing or "pre-1991" location theories, particularly so because Krugman (1991) was thus the first to fully endogenize economic geography in a general equilibrium framework (Ottaviano and Thisse, 2004). In Krugman (1991), space is deliberately homogeneous and the resulting economic geography is an outcome of the model. By adding interregional labour mobility to his 1980 trade model, Krugman (1991) is a trade model as well as a location model. In Krugman (1991), the call from Ohlin (1933), as quoted in the introduction of our paper, to integrate international trade with intra-national or regional economics is answered. Krugman (1991) was the starting point for a whole new sub-field in economic research, the <u>new economic geography</u> literature as first synthesized and summarized by Krugman himself in his 1999 book with Fujita and Venables, namely *The Spatial Economy* (Fujita et al, 1999). In the last section on our appraisal of Krugman's Nobel prize, we will briefly look at the subsequent developments in

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[13] Note that in the middle part of Figure 3 there is some overlap as to the range of the free-ness of trade for the agglomeration and spreading equilibrium which indicates that the model is characterized by path dependency, see Brakman, Garretsen and van Marrewijk (2009, chapter 4) for an explanation.

international (new) trade and (new) economic geography to assess the impact of Krugman's theoretical work on the award winning trinity of increasing returns, transport costs and factor mobility.

5   Looking back and forward

What is today's relevance of Krugman's Nobel prize winning research on (new) trade theory and (new) economic geography? When it comes to trade theory, the answer must be that his analysis of intra-industry trade has become part of that quite selective group of trade theories that undoubtedly constitute the core of modern trade theory. The academic status is in the same league as the Heckscher-Ohlin or Ricardian trade models. On a more general level and this holds in particular for Krugman (1980, 1991), Krugman's research has contributed to the (re)discovery of the importance of location or geography in international economics. In this respect it has also indirectly facilitated the theoretical foundation of well-established empirical relationships, like the gravity model of trade, see Anderson and van Wincoop (2003). Looking back from 2008 to Krugman's trade papers from 1979 and 1980, it is also clear that trade theory has moved on. Two theoretical developments stand out. As opposed to the models discussed above, modern trade models focus on firm heterogeneity and what Baldwin (2006) has dubbed the 2nd unbundling. The former refers to the stylized fact (Bernard et al. 2007) that firms within the same sector are quite different in terms who produced for the international market and starting with Melitz (2003) there is by now a whole new theoretical literature that tries to account for the causes and consequences of firm heterogeneity for international trade (and FDI), see also Helpman (2006). The latter deals with organization of production. In Krugman's trade models, just like in classical trade models, the firm is a black box and firms produce from a single plant or location. It is only (final) goods and consumption that can be unbundled and spatially separated. In recent trade models, and inspired by the growth of offshoring activities, firms can unbundle their own production (Grossman and Rossi-Hansberg, 2008). This leads to a wholly new perspective on trade.

As far as the new economic geography literature is concerned and the status of its initial or core model, Krugman (1991), the main or perhaps the lasting contribution to economic research are twofold. First, just like the work on new trade theory, it has firmly (re-) acquainted mainstream economics with the role of location or geography. Even though this has not led to more collaboration with the discipline of economic geography as such (see Martin, 1999 for an early but still very relevant critique of Krugman, 1991), it has

undoubtedly increased the status of geography in academic and policy work within economics. Secondly, and following Ohlin's 1933 plea to do so, it has narrowed the gap between international economics on the one hand and regional and urban economics on the other hand.

It is beyond the scope of the our paper to discuss the theoretical or empirical research in new economic geography that followed the publication of Krugman (1991), but considerable progress has been made on both the theoretical and analytical front. Theoretically, the analytics of Krugman's core-periphery model are now well-understood (Robert-Nicoud, 2005) and many extensions to the initial menu of agglomeration and spreading forces have been made (see for instance Puga, 1999). Empirically, there are by now many "tests" of the hypotheses deriving from the Krugman (1991) model, as illustrated in the survey by Head and Mayer (2004). New economic geography and the Krugman's 1991 model has also made an impact on the policy front. Baldwin et al (2003) develop theoretical underpinnings of policy implications, and the latest *World Development Report* by the World Bank (2008) is a very good example of policy recommendations and applied analysis that has been much influenced by Krugman's contributions.

But to be able to really extend the analysis of Krugman (1991) and to connect his work with other developments in the literature, much remains to be done. On the theoretical front the main challenge is probably twofold. One is to arrive at more realistic depictions of geography. There is a need to deal with n-regions and asymmetric transport costs (Behrebns and Thisse, 2007, Bosker et al. 2007) as compared to the symmetric 2-region world of Krugman (1991). There is also work to be done when it comes to linking Krugman agglomeration models with the new insights from trade theory on firm heterogeneity (see Baldwin and Okubo, 2006). Empirically, we need better data and tools to really assess the importance of the agglomeration effects emphasized by Krugman (1991) and subsequent models. When it comes to data, the use of micro data seems to be way forward (Combes et al. 2008) and with respect to the tools, the use of spatial econometrics (Fingleton 2006) seems to a promising way to arrive at more conclusive evidence about the empirical relevance of Krugman's new economic geography work.

When the dust settles and we can also put the current 2008 research into perspective, one thing is clear: no matter what the future holds in store when it comes to the (interdependent)

research in economics on trade and geography, there is no doubt in our view as to the lasting impact of Krugman's path-breaking work on trade and geography. As illustrated by the three papers that essentially got him the Nobel prize, which are central in our paper, his work has really changed and improved the way economists think about trade and geography. So let us congratulate Paul Krugman on a job well done!

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