

Schmidheiny, Kurt; Brühlhart, Marius

Working Paper

On the equivalence of location choice models : conditional logit, nested logit and poisson

CESifo Working Paper, No. 2726

Provided in Cooperation with:

Ifo Institute – Leibniz Institute for Economic Research at the University of Munich

Suggested Citation: Schmidheiny, Kurt; Brühlhart, Marius (2009) : On the equivalence of location choice models : conditional logit, nested logit and poisson, CESifo Working Paper, No. 2726, Center for Economic Studies and ifo Institute (CESifo), Munich

This Version is available at:

<https://hdl.handle.net/10419/30694>

Standard-Nutzungsbedingungen:

Die Dokumente auf EconStor dürfen zu eigenen wissenschaftlichen Zwecken und zum Privatgebrauch gespeichert und kopiert werden.

Sie dürfen die Dokumente nicht für öffentliche oder kommerzielle Zwecke vervielfältigen, öffentlich ausstellen, öffentlich zugänglich machen, vertreiben oder anderweitig nutzen.

Sofern die Verfasser die Dokumente unter Open-Content-Lizenzen (insbesondere CC-Lizenzen) zur Verfügung gestellt haben sollten, gelten abweichend von diesen Nutzungsbedingungen die in der dort genannten Lizenz gewährten Nutzungsrechte.

Terms of use:

Documents in EconStor may be saved and copied for your personal and scholarly purposes.

You are not to copy documents for public or commercial purposes, to exhibit the documents publicly, to make them publicly available on the internet, or to distribute or otherwise use the documents in public.

If the documents have been made available under an Open Content Licence (especially Creative Commons Licences), you may exercise further usage rights as specified in the indicated licence.

On the Equivalence of Location Choice Models: Conditional Logit, Nested Logit and Poisson

KURT SCHMIDHEINY
MARIUS BRÜLHART

CESIFO WORKING PAPER NO. 2726
CATEGORY 12: EMPIRICAL AND THEORETICAL METHODS
JULY 2009

An electronic version of the paper may be downloaded
• *from the SSRN website:* www.SSRN.com
• *from the RePEc website:* www.RePEc.org
• *from the CESifo website:* www.CESifo-group.org/wp

On the Equivalence of Location Choice Models: Conditional Logit, Nested Logit and Poisson

Abstract

It is well understood that the two most popular empirical models of location choice - conditional logit and Poisson - return identical coefficient estimates when the regressors are not individual specific. We show that these two models differ starkly in terms of their implied predictions. The conditional logit model represents a zero-sum world, in which one region's gain is the other regions' loss. In contrast, the Poisson model implies a positive-sum economy, in which one region's gain is no other region's loss. We also show that all intermediate cases can be represented as a nested logit model with a single outside option. The nested logit turns out to be a linear combination of the conditional logit and Poisson models. Conditional logit and Poisson elasticities mark the polar cases and can therefore serve as boundary values in applied research.

JEL Code: C25, R30, H73.

Keywords: firm location, residential choice, conditional logit, nested logit, Poisson count model.

Kurt Schmidheiny
Department of Economics
University Pompeu Fabra
Ramon Trias Fargas 25-27
Spain – 08005 Barcelona
kurt.schmidheiny@upf.edu

Marius Brülhart
Department of Economics
School of HEC
University of Lausanne
Switzerland – 1015 Lausanne
Marius.Brulhart@unil.ch

July 14th, 2009

We are grateful to Paulo Guimaraes and his coauthors for allowing us to use their data set, and to seminar participants at Pompeu Fabra and at the University of Barcelona for useful comments. Financial support from the Spanish Ministry of Science and Innovation (Ramon y Cajal and Consolider SEJ2007-64340), the Swiss National Science Foundation (grants 100012-113938 and PDFMP1-123133), and from the EU's Sixth Framework Program (“Micro-Dyn” project) is gratefully acknowledged.

1 Introduction

Location choices by households and firms are of interest to economists for numerous reasons, ranging from the determinants of residential segregation patterns in cities to the design of national tax policy. Given the discrete nature of such choices, they are typically modelled by empirical researchers through McFadden's (1974) conditional logit framework.¹ The appeal of this approach lies in its formal link between the theoretical objective function of a representative location-seeking agent and the likelihood function of the empirical model.

Mostly out of a perception of greater computational ease, researchers have resorted to Poisson count estimation as an alternative approach to the conditional logit.² Guimaraes, Figueiredo and Woodward (2003), henceforth GFW, have shown that, with purely location-specific locational determinants or with determinants that are specific to locations and to groups of agents, the conditional logit and Poisson estimators return identical parameter estimates. In this sense, the two estimators are equivalent, and the rigorous link to the theory offered by the conditional logit model therefore applies identically to the Poisson. This useful result has already been applied widely in the location choice literature.³

We show that the identical coefficient estimates resulting from the two estimation strategies in fact have fundamentally different economic implications. The conditional logit model implies that the aggregate number of agents is fixed and that differences across locations affect only the distribution of those agents across those locations. Hence, an additional agent attracted to location j means one less agent among the other locations in the relevant set, $i \neq j$. In the Poisson model, however, an additional agent attracted to location j has no impact on the number of agents in the remaining locations and thus raises the aggregate number of agents, summed across i and j , by one. Thus, the conditional logit model and the Poisson model can be viewed as polar cases, with the former representing zero-sum reallocations of firms or households across locations and the latter implying a positive-sum world.⁴

We also show that intermediate cases between these two extremes can be represented by a nested logit model featuring a generic outside option. This approach returns the same

¹For studies of firm location choices using the conditional logit approach, see, e.g., Carlton (1983), Head, Ries and Swenson (1995), Guimaraes, Figueiredo and Woodward (2000), Head and Mayer (2004), Crozet, Mayer and Mucchielli (2004), and Devereux, Griffith and Simpson (2007). For corresponding studies of household location choices, see, e.g., Ellickson (1981), Quigley (1985), Nechyba and Strauss (1998), Schmidheiny (2006), and Bayer, Ferreira and McMillan (2007).

²See, e.g., Papke (1991), Becker and Henderson (2000), List (2001), Guimaraes, Figueiredo and Woodward (2004), and Holl (2004), for studies of firms' location choices; and Flowerdew and Aitkin (1982) and Börsch-Supan (1990) for studies of individual migration choices.

³Recent studies invoking the GFW equivalence result include Duranton, Gobillon and Overman (2006), Brülhart, Jametti and Schmidheiny (2007), Arzaghi and Henderson (2008), Davis and Henderson (2008), and Coeurdacier, De Santis and Aviat (2009).

⁴For recent research on the cross-region effects of region-specific policies aimed at attracting firms, see, e.g., Greenstone and Moretti (2003), Chirinko and Wilson (2008), and Wilson (2009).

parameter estimates as the two other estimators. The nested logit in fact can be written as a linear combination of the conditional logit and Poisson models, with a single “rivalness parameter” representing the closeness of the nested logit to the conditional logit (and thus the distance from the Poisson). Conditional logit and Poisson elasticities mark the polar cases and can therefore serve as boundary values in applied research.

The paper is structured as follows. In Section 2, we formally derive the commonalities and differences among the conditional logit, Poisson and nested logit models. Empirical implications and an illustration are presented in Section 3. Section 4 concludes.

2 The models

We denote agents with $f = 1, \dots, N$ and regions with $j = 1, \dots, J$. For simplicity, we shall frame our discussion in terms of corporate location decisions, and therefore relate to f as “firms”.

Following GFW, we first assume the determinants of locational attractiveness to be purely region specific, such that they affect all firms symmetrically (case A). The K observable characteristics of each region are given by the $(K \times 1)$ vector x_j . We then relax this assumption, and allow locational attractiveness to be region-industry specific (case B).

The random variable n_j represents the count of firms in region j , whereas N_j denotes the number of firms actually observed in region j . Analogously, the random variable n represents the total number of firms, whereas N denotes the observed total number of firms.

2.1 Case A: industry-invariant locational determinants

2.1.1 Conditional logit

Suppose that firm f 's profit in region j is determined by the linear model $\pi_{fj} = x_j' \beta + \varepsilon_{fj}$, where β is a $(K \times 1)$ vector of coefficients. Then, the conditional logit model is defined by the assumption that the random term ε_{fj} is independent across f and j and follows an extreme-value type 1 distribution. With this assumption, the probability that a given firm f chooses region j rather than another region is given by

$$P_{j|f} = P_j = \frac{e^{x_j' \beta}}{\sum_{i=1}^J e^{x_i' \beta}}, \quad (1)$$

where $\sum_j P_{j|f} = 1$ for all f . Since locational characteristics x_j are assumed here to affect all firms symmetrically, this probability also represents the share of firms that will choose region j .

The parameter β can be estimated by maximum likelihood. We can write the log likelihood as

$$\log L(\beta) = \sum_{j=1}^J N_j \log P_j = \sum_{j=1}^J N_j x'_j \beta - \sum_{j=1}^J [N_j \log(\sum_{i=1}^J e^{x'_i \beta})]. \quad (2)$$

The conditional logit model implicitly assumes that the total number of firms n is given and does not depend on the locational characteristics x . The expected number of firms in region j , $E(n_j)$ is therefore simply

$$E(n_j) = nP_j = n \frac{e^{x'_j \beta}}{\sum_{i=1}^J e^{x'_i \beta}}. \quad (3)$$

The percentage change in the expected number of firms in region j , $E(n_j)$, with respect to a unit change in the k -th locational characteristic of region j itself is given respectively by the *own-region semi-elasticity*:

$$\epsilon_{jj} = \frac{\partial \log E(n_j)}{\partial x_{jk}} = (1 - P_j)\beta_k. \quad (4)$$

Similarly, the percentage change in the expected number of firms in another region, $E(n_{i \neq j})$, with respect to a unit change in j 's k -th locational characteristic is given by the *cross-region semi-elasticity*:

$$\epsilon_{ij} = \frac{\partial \log E(n_i)}{\partial x_{jk}} = -P_j \beta_k. \quad (5)$$

For simplicity, we shall henceforth refer to these and all subsequently presented semi-elasticities as “elasticities”. Hence, all “elasticities” derived and calculated in this paper in fact are semi-elasticities.

The own-region elasticity (4) shows that by enhancing its attractiveness a region will increase its expected number of firms, and the cross-region elasticity (5) implies that one region's increased attractiveness to firms will reduce the number of firms choosing other regions: one region's gain is another region's loss. Moreover, a simple comparison of the two elasticities shows that small regions (in terms of P_j , the share of firms they host) are predicted by the conditional logit model to find their own firm counts to be relatively elastic to changes in their own locational characteristics, while not affecting firm counts in other regions as much as large regions.

We now turn from the viewpoint of individual regions to an analysis of what the conditional

logit model implies for the total number of firms among the J regions. By definition,

$$E(n) = \sum_{j=1}^J E(n_j) = n = N. \quad (6)$$

Hence, the expected total number of firms is equal to the observed total, N , irrespective of regressors and parameters. This again shows the “zero sum” aspect of the conditional logit model, where the implied problem is one of allocating an exogenously fixed number of firms over a set of regions. It also follows logically that changes in the locational attractiveness of individual regions will not affect the total number of firms. Formally, the elasticity of the expected total firm count relative to a change in one of the K locational characteristics of any particular region j is zero:

$$\epsilon_j = \frac{\partial \log E(n)}{\partial x_{jk}} = 0.$$

2.1.2 Poisson

The Poisson estimator is based on the assumption that n_j is independently Poisson distributed with region-specific mean

$$E(n_j) = e^{\alpha + x'_j \beta}. \quad (7)$$

Here too, β can be estimated by maximum likelihood. We can write the concentrated log likelihood as

$$\log L(\beta) = \sum_{j=1}^J N_j x'_j \beta - \sum_{j=1}^J [N_j \log(\sum_{i=1}^J e^{x'_i \beta})] - \sum_{j=1}^J \log N_j! - N + N \log N. \quad (8)$$

When comparing this to (2), the point made by GFW is plain to see: the log likelihood functions of the two models are identical up to a constant, and maximum likelihood estimation therefore yields identical parameter estimates $\hat{\beta}$.

The expected share of firms in region j can be written as

$$P_j = \frac{E(n_j)}{\sum_{i=1}^J E(n_i)} = \frac{e^{\alpha + x'_j \beta}}{\sum_{i=1}^J e^{\alpha + x'_i \beta}} = \frac{e^{x'_j \beta}}{\sum_{i=1}^J e^{x'_i \beta}}, \quad (9)$$

which is exactly the same expression as (1), for the conditional logit model. This equivalence lies at the heart of the GFW result:

Observation 1 (Guimaraes, Figueiredo and Woodward, 2003) *The log likelihood functions for the conditional logit and the Poisson model are identical up to a constant, and maximum likelihood estimation therefore yields identical parameter estimates $\hat{\beta}$.*

The elasticity of the expected number of firms in region j , $E(n_j)$, with respect to a change in the k -th locational characteristic of region j itself, and by that of another region $i \neq j$, is given respectively by the *own-region elasticity*

$$\epsilon_{jj} = \frac{\partial \log E(n_j)}{\partial x_{jk}} = \beta_k \quad (10)$$

and by the *cross-region elasticity*

$$\epsilon_{ij} = \frac{\partial \log E(n_i)}{\partial x_{jk}} = 0. \quad (11)$$

Comparing these elasticities to their conditional-logit equivalents (4) and (5), we observe the following differences.

Observation 2 *The Poisson model implies more elastic responses by firm counts to given changes in own-region characteristics than the conditional logit model.*

Observation 3 *Unlike in the conditional logit model, in the Poisson model, one region's change in locational attractiveness has no impact on the number of firms located among any of the $J - 1$ other regions.*

Hence, even though the estimated parameters $\hat{\beta}$ will be invariant to the choice of model, their implied predictions differ starkly. The conditional logit model implies a zero-sum allocation process of a fixed number of firms over the J jurisdictions. In contrast, in the Poisson model new firms are non-rivalrous, in the sense that adjustment to one regions's locational characteristics works not through changes in firm numbers among the $J - 1$ other regions but from changes either in the supply of local entrepreneurship or in firms attracted from or repelled to somewhere outside the considered set of J regions.

Moving again from the viewpoint of individual regions to an analysis of the model's implications for the total number of firms among the J regions, and using (7), we find that

$$E(n) = \sum_{i=1}^J E(n_i) = \sum_{i=1}^J e^{\alpha + x'_i \beta} = e^\alpha \sum_{i=1}^J e^{x'_i \beta}.$$

Comparing this expression with its conditional logit equivalent (6), we note that the expected total number of firms is now not generally equal to the observed total number of firms, N , but depends on the regressors and parameters.⁵ The Poisson model thus implies that a change in a region's locational attractiveness will affect the sum of firms active in the

⁵Note that the predicted total number of firms *at the estimated coefficients and actual data* corresponds to the observed total of firms in the Poisson model just as it does in the conditional logit model. In symbols, $E(n|\hat{\alpha}, \hat{\beta}) = N$.

J regions. Specifically, the elasticity of the expected total firm count with respect to a change in one of the K locational characteristics of any particular region j is given by

$$\epsilon_j = \frac{\partial \log E(n)}{\partial x_{jk}} = \frac{e^{x'_j \beta}}{\sum_{i=1}^J e^{x'_i \beta}} \beta_k = \frac{E(n_j)}{E(n)} \beta_k = P_j \beta_k.^6$$

Observation 4 *In the Poisson model, an increase (decrease) in one region's locational attractiveness increases (decreases) the total of firms summed across the J regions. In the conditional logit model, a change in one region's locational attractiveness leaves the total of firms summed across the J regions unchanged.*

2.1.3 Nested logit

Observations 2, 3 and 4 show that the two models are the polar cases of a continuum of relative adjustment margins, ranging from reallocations purely *within* the set of alternatives considered (conditional logit) to reallocations purely *between* that set and some outside option (Poisson). We now turn to a micro-founded approach that covers this whole continuum and thus encompasses the polar cases.

Suppose that firms make two sequential choices. At the first stage, they choose between locating in one of the J regions considered (which could stand for “domestic” regions) and an outside option $j = 0$ (which could stand for locating “abroad” or for remaining inactive). At the second stage, they pick one of the J regions. Like in the conditional logit model, firm f 's profit in region $j > 0$ is determined by a linear function of the region-specific characteristics x_j , such that $\pi_{fj} = x'_j \gamma + \nu_{fj}$. Firm f 's profit associated with the outside option is given by $\pi_{f0} = \delta + \nu_{f0}$, where δ summarizes the exogenously fixed locational attractiveness of the outside option. The stochastic term ν_{f0} is assumed to follow a generalized extreme value distribution as in McFadden (1978).⁷ This leads to a nested logit model with one degenerate “nest” that includes $j = 0$ only and one other “nest” that includes all regions $j > 0$. This two-stage structure assumes independence between ν_{f0} and ν_{fj} for all $j > 0$, and non-negative correlation $(1 - \lambda^2)$ across ν_{fj} for all $j > 0$; where $0 < \lambda \leq 1$, sometimes called the “log-sum” coefficient, measures the importance of the domestic nest as a whole relative to the outside option.

In this setting, the probability that a particular firm f chooses the outside option $j = 0$ is given by

$$P_0 = \frac{e^\delta}{e^\delta + (\sum_{j=1}^J e^{x'_j \beta})^\lambda}, \quad (12)$$

⁶We define $P_j \equiv E(n_j)/E(n) \neq E(n_j/n)$ in the Poisson model. Using this definition, $P_j = e^{x'_j \beta} / \sum_{i=1}^J e^{x'_i \beta}$ in both the conditional logit and the Poisson model.

⁷The specific density function assumed over $\{0, J\}$ is $F(\nu_f) = \exp \left[-(\sum_{j=1}^J e^{-\nu_{fj}/\lambda})^\lambda - e^{-\nu_{f0}} \right]$.

and the probability that it chooses a particular region $j > 0$ among the J regions of interest is

$$P_j = \frac{e^{x'_j\beta} (\sum_{i=1}^J e^{x'_i\beta})^{\lambda-1}}{e^\delta + (\sum_{i=1}^J e^{x'_i\beta})^\lambda} = P_{j>0} \cdot P_{j|j>0},$$

where we reparametrize $\beta = \gamma/\lambda$. This implies that, unlike in the conditional logit, the estimated regression parameters $\hat{\beta}$ are not identical to the structural parameters of the underlying profit function.

The choice probabilities P_j can be decomposed into (a) the probability of choosing any of the J regions, $P_{j>0} = 1 - P_0$, and (b) the probability of choosing a specific region j given that the firm chooses to set up in one of the J regions,

$$P_{j|j>0} = \frac{e^{x'_j\beta}}{\sum_{i=1}^J e^{x'_i\beta}}. \quad (13)$$

The parameter β can again be estimated by maximum likelihood. We can write the concentrated log likelihood as

$$\log L(\beta) = \sum_{j=1}^J N_j x'_j \beta - \sum_{j=1}^J [N_j \log(\sum_{i=1}^J e^{x'_i\beta})] + N_0 \log(N_0) + N \log(N) - (N + N_0) \log(N + N_0),$$

where δ and λ cancel out when we substitute the first-order condition $\partial \log L / \partial \delta = 0$ into $L(\beta, \delta, \lambda)$.⁸ N is the number of firms locating in any of the regions $j > 0$, and N_0 is the number of firms choosing the outside option $j = 0$. Note that β can be estimated without observing N_0 .

Observation 5 *The log likelihood functions for the conditional logit, the Poisson and the nested logit model with a single outside option are identical up to a constant, and maximum likelihood estimation therefore yields identical parameter estimates $\hat{\beta}$.*

The ratio (13) is identical to its equivalents in the conditional logit and Poisson models, (1) and (9). This correspondence among the three models lies at the heart of Observation 5, which extends the GFW result to the nested logit case with a single outside option.

⁸This expression is obtained as follows:

$$\begin{aligned} \log L(\beta, \delta, \lambda) &= N_0 \log P_0 + \sum_{j=1}^J N_j \log P_j \\ &= N_0 \log \left(\frac{e^\delta}{e^\delta + (\sum_{i=1}^J e^{x'_i\beta})^\lambda} \right) + \sum_{j=1}^J \left[N_j \log \left(\frac{e^{x'_j\beta} (\sum_{i=1}^J e^{x'_i\beta})^{\lambda-1}}{e^\delta + (\sum_{i=1}^J e^{x'_i\beta})^\lambda} \right) \right]. \end{aligned}$$

The first-order condition with respect to δ is $\partial \log L / \partial \delta = N_0 - (N + N_0) e^\delta / [e^\delta + (\sum_{i=1}^J e^{x'_i\beta})^\lambda] = 0$. The estimated $\hat{\delta}$ can therefore be expressed as a function of the estimated $\hat{\beta}$ and $\hat{\lambda}$: $e^{\hat{\delta}} = N_0 / N \cdot (\sum_{i=1}^J e^{x'_i\hat{\beta}})^\lambda$. When we substitute $e^{\hat{\delta}}$ in $\log L(\beta, \delta, \lambda)$, λ also cancels out.

The expected number of firms in region $j > 0$ is

$$E(n_j) = (n + n_0)P_j = (n + n_0) \frac{e^{x'_j\beta} (\sum_{i=1}^J e^{x'_i\beta})^{\lambda-1}}{e^\delta + (\sum_{i=1}^J e^{x'_i\beta})^\lambda}. \quad (14)$$

The *own-region elasticity* of the expected number of firms, $E(n_j)$, relative to locational characteristics is given by

$$\epsilon_{jj} = \frac{\partial \log E(n_j)}{\partial x_{jk}} = [1 - P_{j|j>0}(1 - \lambda P_0)]\beta_k, \quad (15)$$

and the *cross-region elasticity* is given by

$$\epsilon_{ij} = \frac{\partial \log E(n_i)}{\partial x_{jk}} = -P_{j|j>0}(1 - \lambda P_0)\beta_k. \quad (16)$$

We can now compare the own- and cross-region elasticities of the three models. Simple inspection of elasticities (4), (5), (10), (11), (15) and (16) leads to the following observation.

Observation 6 *The nested-logit own-region and cross-region elasticities lie between their conditional logit and Poisson counterparts.*

Once more, we now move from the analysis of firm counts in individual regions to the total number of firms that are active in the J regions. Using (14) and (12), we find that

$$E(n) = (n + n_0) \frac{(\sum_{j=1}^J e^{x'_j\beta})^\lambda}{e^\delta + (\sum_{j=1}^J e^{x'_j\beta})^\lambda} = (n + n_0)P_{j>0}.$$

The expected total number of firms active in the J regions is simply given by the share of potential firms that decide to become active in one of those regions. As in the Poisson model, the expected total number of firms is not generally equal to the observed total number of firms, N , but depends on the regressors and parameters, including those for the outside option.⁹ The elasticity of the expected total firm count relative to a change in one of the K locational characteristics of any particular region j is given by

$$\epsilon_j = \frac{\partial \log E(n)}{\partial x_{jk}} = \frac{\lambda e^\delta e^{x'_j\beta} (\sum_{i=1}^J e^{x'_i\beta})^{-1} \beta_k}{e^\delta + (\sum_{i=1}^J e^{x'_i\beta})^\lambda} = \lambda P_0 P_{j|j>0} \beta_k.$$

Observation 7 *Like the Poisson, the nested logit model implies that a change in a region's locational attractiveness will affect the total of firms summed across the J regions.*

Here, the responsiveness of the aggregate firm number is due to the effect on the decisions

⁹As in the Poisson and conditional logit models, the predicted total number of firms among the J regions at the estimated coefficients and actual data corresponds to the observed total: $E(n|\hat{\beta}, \hat{\delta}, \hat{\lambda}) = N$.

Table 1: Comparing implied elasticities (case A)

	Conditional Logit	Nested Logit	Poisson
$\epsilon_{jj} = \frac{\partial \log E(n_j)}{\partial x_{jk}}$	$(1 - P_{j j>0})\beta_k$	$[1 - P_{j j>0}(1 - \lambda P_0)]\beta_k$	β_k
$\epsilon_{ij} = \frac{\partial \log E(n_i)}{\partial x_{jk}}$	$-P_{j j>0}\beta_k$	$-P_{j j>0}(1 - \lambda P_0)\beta_k$	0
$\epsilon_j = \frac{\partial \log E(n)}{\partial x_{jk}}$	0	$\lambda P_0 P_{j j>0}\beta_k$	$P_{j j>0}\beta_k$

Notes: $P_{j|j>0} = E(n_j)/E(n)$, $P_0 = E(n_0)/E(n + n_0)$

taken by firms that would have chosen the outside option in the absence of a change in regional attractiveness.

2.1.4 A synthesis of the three models

We can now pull together the salient features of the three models. First, we consider the impact of a change in the attractiveness of an individual region on the number of firms in that region and across the $J - 1$ remaining regions. Table 1 gathers the own-region, cross-region and aggregate elasticities implied by the three models.

In order to compare these elasticities, we define $\rho = 1 - \lambda P_0$ which satisfies $0 \geq \rho \geq 1$ under the standard nested logit assumption $0 < \lambda \leq 1$. We call ρ the *rivalness parameter*. It allows us to write the nested logit elasticities as a linear combination of their conditional logit and Poisson equivalents: $\epsilon_{jj}^{\text{nlogit}} = \rho \epsilon_{jj}^{\text{clogit}} + (1 - \rho) \epsilon_{jj}^{\text{Poisson}}$, $\epsilon_{ij}^{\text{nlogit}} = \rho \epsilon_{ij}^{\text{clogit}}$ and $\epsilon_j^{\text{nlogit}} = (1 - \rho) \epsilon_j^{\text{Poisson}}$. The rivalness parameter therefore acts as a summary measure of the position of the data generating process between the two polar cases, conditional logit ($\rho = 1$) and Poisson ($\rho = 0$). One may think of ρ as capturing of the relative importance of the outside option: as $\rho \rightarrow 0$, competition among the J regions becomes unimportant relative to the weight of the outside option, while with $\rho \rightarrow 1$, the outside option becomes negligible and any reallocations have to occur within the set of the J regions.

We can also establish rankings of the elasticities implied by the three models. Provided that $\beta \neq 0$, the ranking of own-region elasticities is (c.f. Observations 2 and 6)

$$|\epsilon_{jj}^{\text{Poisson}}| > |\epsilon_{jj}^{\text{nlogit}}| > |\epsilon_{jj}^{\text{clogit}}| > 0,$$

while the ranking of cross-regions elasticities is just the reverse (c.f. Observations 3 and 6),

$$|\epsilon_{ij}^{\text{clogit}}| > |\epsilon_{ij}^{\text{nlogit}}| > |\epsilon_{ij}^{\text{Poisson}}| = 0.$$

and the ranking of aggregate elasticities is again (c.f. Observations 4 and 7)

$$|\epsilon_j^{\text{Poisson}}| > |\epsilon_j^{\text{nlogit}}| > |\epsilon_j^{\text{clogit}}| > 0.$$

2.2 Case B: industry-specific locational determinants

Consider now that we observe K characteristics x_{sj} for every region j and industry s . Hence, we again do not observe firm-specific regional attributes, but we now allow for these attributes to differ across *groups* of firms, best thought of as industries. We maintain the notation x_j for the subset of locational determinants that are constant across industries. Furthermore, n_{js} is the number of firms in region j and industry s , n_s is the observed number of industry- s firms across all regions, n is the total number of firms, and N stands for the corresponding *observed* firm count in the sample.

The *grouped conditional logit* model is given by the probability that a given firm f of industry s chooses region j rather than another region:

$$P_{j|f} = P_{j|s} = \frac{e^{x'_{sj}\beta}}{\sum_{i=1}^J e^{x'_{si}\beta}},$$

where $\sum_j P_{j|f} = 1$. $P_{j|s}$ is the probability for a particular firm to choose region j given that the firm belongs to industry s .

The *grouped Poisson* model is given by

$$E(n_{sj}) = e^{\alpha_s + x'_{sj}\beta},$$

where α_s is an industry-specific constant.

Finally, the *grouped nested logit* model is given by the probability that a given firm f of industry s chooses either the outside option $j = 0$,

$$P_{0|s} = \frac{e^{\delta_s}}{e^{\delta_s} + (\sum_{j=1}^J e^{x'_{sj}\gamma/\lambda})^\lambda} = \frac{e^{\delta_s}}{e^{\delta_s} + (\sum_{j=1}^J e^{x'_{sj}\beta})^\lambda},$$

or a particular domestic region $j > 0$,

$$P_{j|s} = \frac{e^{x'_{sj}\beta} (\sum_{i=1}^J e^{x'_{si}\beta})^{\lambda-1}}{e^{\delta_s} + (\sum_{i=1}^J e^{x'_{si}\beta})^\lambda} = P_{j>0|s} \cdot P_{j|j>0,s} = (1 - P_{0|s})P_{j|j>0,s},$$

where δ_s is an industry-specific constant, and $\beta = \gamma/\lambda$. $P_{j>0|s} = 1 - P_{0|s}$ is the probability

Table 2: Comparing implied elasticities (case B)

	Conditional Logit	Nested Logit	Poisson
Region-industry specific regressor x_{sjk} :			
(a)	$\frac{\partial \log E(n_{sj})}{\partial x_{sjk}} \quad \beta_k(1 - P_{j j>0,s})$	$\beta_k[1 - P_{j j>0,s}(1 - \lambda P_{0 s})]$	β_k
(b)	$\frac{\partial \log E(n_{si})}{\partial x_{sjk}} \quad -\beta_k P_{j j>0,s}$	$-\beta_k P_{j j>0,s}(1 - \lambda P_{0 s})$	0
(c)	$\frac{\partial \log E(n_s)}{\partial x_{sjk}} \quad 0$	$\beta_k P_{j j>0,s} \lambda P_{0 s}$	$\beta_k P_{j j>0,s}$
(d)	$\frac{\partial \log E(n_j)}{\partial x_{sjk}} \quad \beta_k(1 - P_{j j>0,s})P_{s j}$	$\beta_k[1 - P_{j j>0,s}(1 - \lambda P_{0 s})]P_{s j}$	$\beta_k P_{s j}$
(e)	$\frac{\partial \log E(n_i)}{\partial x_{sjk}} \quad -\beta_k P_{j j>0,s} P_{s i}$	$-\beta_k P_{j j>0,s}(1 - \lambda P_{0 s})P_{s i}$	0
(f)	$\frac{\partial \log E(n)}{\partial x_{sjk}} \quad 0$	$\beta_k P_{s j} P_j \lambda P_{0 s}$	$\beta_k P_{s j} P_{j j>0}$
Region specific regressor x_{jk} :			
(g)	$\frac{\partial \log E(n_j)}{\partial x_{jk}} \quad \beta_k \sum_{s=1}^S (1 - P_{j j>0,s}) P_{s j}$	$\beta_k \sum_{s=1}^S [1 - P_{j j>0,s}(1 - \lambda P_{0 s})] P_{s j}$	β_k
(h)	$\frac{\partial \log E(n_i)}{\partial x_{jk}} \quad -\beta_k \sum_{s=1}^S P_{j j>0,s} P_{s i}$	$-\beta_k \sum_{s=1}^S P_{j j>0,s}(1 - \lambda P_{0 s}) P_{s i}$	0
(i)	$\frac{\partial \log E(n)}{\partial x_{jk}} \quad 0$	$\beta_k P_j \sum_{s=1}^S (\lambda P_{0 s} P_{s j})$	$\beta_k P_{j j>0}$

Notes: $P_{j|j>0,s} = E(n_{sj})/E(n_s)$, $P_{0|s} = E(n_{s0})/E(n_s + n_{s0})$, $P_{s|j} = E(n_{sj})/E(n_j)$. $P_{s|j}$ is the fraction of firms in industry s in a given region j .

that a given industry- s firm chooses any domestic region $j > 0$, and

$$P_{j|j>0,s} = \frac{e^{x'_{sj}\beta}}{\sum_{i=1}^J e^{x'_{si}\beta}} \quad (17)$$

is the probability that such a firm chooses a particular domestic region conditional on not choosing the outside option.

As in case A, the three models are observationally equivalent in a cross section of domestic firm choices and yield identical estimates for the parameter vector β . This has been shown by GFW for the grouped conditional logit and the grouped Poisson models, and we show it in the Appendix for the grouped nested logit model.

Table 2 summarizes the implied elasticities in the three grouped models (see the Appendix for derivations). As in case A, the elasticities in the grouped nested logit model are (industry-specific) linear combinations of their conditional logit and Poisson equivalents: $\epsilon_{..}^{\text{logit}} = \rho_s \epsilon_{..}^{\text{clogit}} + (1 - \rho_s) \epsilon_{..}^{\text{Poisson}}$ where $\rho_s = 1 - \lambda P_{0|s}$.

3 Estimation

3.1 Elasticity bounds

We have shown that estimation of any of the three models will yield identical parameter estimates $\hat{\beta}$. The additional parameters λ , δ and α in the nested logit model are not identified but irrelevant for the estimation of β . Hence, it is impossible to discriminate formally between these three model based on cross-section data. And yet, the implied elasticities differ substantially. In previous research, reported elasticities were based either on the conditional logit model or the Poisson model, without justification of the particular choice made or, mistakenly in this respect, by referring to the equivalence of the two models as established by GFW.

What can researchers do if they are not willing to make this choice by assumption but rely on cross-sectional data? We propose in this situation that one calculate the elasticities of both the conditional logit and the Poisson model and report these predictions as bounds for the true effects. As shown in Observation 6, intermediate values can be rationalized by a nested logit model.

The computation of both conditional logit and Poisson elasticities requires that one calculate predicted probabilities. In terms of case A (Table 1), the predicted probability is obtained as follows:

$$\hat{P}_{j|j>0} = \frac{e^{x'_j \hat{\beta}}}{\sum_{i=1}^J e^{x'_i \hat{\beta}}}, \quad (18)$$

while for case B (Table 2), there are three predicted probabilities to be computed:

$$\hat{P}_{j|j>0,s} = \frac{e^{x'_{sj} \hat{\beta}}}{\sum_{i=1}^J e^{x'_{si} \hat{\beta}}}, \quad (19)$$

$$\hat{P}_{s|j} = \frac{e^{x'_{sj} \hat{\beta}}}{\sum_{r=1}^S e^{x'_{rj} \hat{\beta}}}, \text{ and} \quad (20)$$

$$\hat{P}_{j|j>0} = \frac{\sum_{r=1}^S e^{x'_{rj} \hat{\beta}}}{\sum_{r=1}^S \sum_{i=1}^J e^{x'_{ri} \hat{\beta}}}. \quad (21)$$

3.2 An example

By way of an illustration, we take the data on location choices in Portugal by foreign-owned plants used in Guimaraes *et al.* (2000, 2003), and we report the elasticities implied by the coefficients of their regression model. The data cover a cross section of 758 location choices among 275 Portuguese regions by firms belonging to one of 151 industries.¹⁰ Their region-industry level regressor of main interest, x_{sjk} , is “industry-specific agglomeration”, defined as

¹⁰We follow GFW by referring to industry-year pairs as “industries”. The 151 industries in their data set are combinations of 27 three-digit manufacturing sectors and seven sample years, ranging from 1985 to 1991.

Table 3: Comparing implied elasticities in an example of case B

	large region j		small region j		
	CL	Poisson	CL	Poisson	
Region-industry specific regressor x_{sjk} :					
(a)	$\frac{\partial \log E(n_{sj})}{\partial x_{sjk}}$	2.9290	3.1883	3.18778	3.18832
(b)	$\frac{\partial \log E(n_{si})}{\partial x_{sjk}}$	-0.2593	0	-0.00054	0
(c)	$\frac{\partial \log E(n_s)}{\partial x_{sjk}}$	0	0.2593	0	0.00054
(d)	$\frac{\partial \log E(n_j)}{\partial x_{sjk}}$	0.1110	0.1208	0.09624	0.09626
(e)	$\frac{\partial \log E(n_i)}{\partial x_{sjk}}$	-0.0095	0	-0.00002	0
(f)	$\frac{\partial \log E(n)}{\partial x_{sjk}}$	0	0.0106	0	0.00002
Region specific regressor x_{jk} :					
(g)	$\frac{\partial \log E(n_j)}{\partial x_{jk}}$	0.3873	0.42577	0.42548	0.42577
(h)	$\frac{\partial \log E(n_i)}{\partial x_{jk}}$	-0.0378	0	-0.00004	0
(i)	$\frac{\partial \log E(n)}{\partial x_{jk}}$	0	0.0374	0	0.00010

Notes: large region: $j = \text{Lisbon}$; small region: $j = \text{Oleiros}$; $i = \text{Porto}$ in rows (e) and (h); $k = \text{“industry-specific agglomeration”}$ in rows (a) to (f), $k = \text{“total manufacturing agglomeration”}$ in rows (g) to (i); sector: $s = \text{ISIC 351 (Industrial Chemicals)}$ in 1989 in rows (a) to (f); any sector in rows (g) to (i).

the share of regional employment in the same industry as the relevant firm. Their region level regressor of main interest, x_{jk} , is “total manufacturing agglomeration”, defined as the log of aggregate manufacturing employment per square kilometer.

Taking their estimated parameters and computing the empirical probabilities (18)-(21), we can calculate all the implied elasticities of Table 2. Since the probabilities (18)-(21) vary by region and industry, we need to select specific cases for the computation of elasticities. We provide illustrations for two base regions j : Lisbon, the largest region in terms of $\hat{P}_{j|j>0}$, and Oleiros, the smallest region in terms of $\hat{P}_{j|j>0}$ that still had non-zero firm counts in the larger industry considered.¹¹

Table 3 shows the implied elasticities for changes in a region-industry specific regressor and in a region specific regressor. We can take these estimates to illustrate Observations 2 to 4.

- Observation 2: Own-region elasticities are larger in the Poisson model than in the

¹¹Where a comparison region i needs to be specified for the computation of cross elasticities, we choose Porto, the second largest region in the data set. Where an industry s needs to be specified, we choose Industrial Chemicals (ISIC 351) in 1989, the largest sector-year pair in the dataset (31 observed choices, i.e. 4 percent of the total of 758 choices).

conditional logit (rows (a), (d) and (g)). We can see that the difference between implied own-region elasticities is non-trivial for the large region (some 10 percent) but very small for the small region (less than 0.1 percent). This illustrates that the difference between implied own-region elasticities of the two models vanishes as the number of regions grows large and individual regions therefore become small.

- Observation 3: All Poisson cross-region elasticities are zero (rows (b), (e) and (h)).
- Observation 4: In the conditional logit model, the total number of firms (across all of Portugal) is invariant to changes in the values of x_{sjk} or x_{jk} whereas in the Poisson model the total changes with x_{sjk} or x_{jk} (rows (c), (f) and (i)). The effect on the total number of firms of a given change in x_{sjk} is stronger if the change occurs in a large region.

These computations illustrate the qualitatively different predictions implied by the conditional logit and Poisson models. With $J = 275$ spatial alternatives and $s = 151$ industries, the underlying data set is highly disaggregated, implying relatively modest quantitative differences between implied elasticities. Nonetheless, even here some of the differences are far from negligible. Perhaps the most striking difference appears in row (c) of Table 3. A one-unit change in x_{sjk} of Lisbon leaves the number of Portuguese plants in industry s unchanged in the conditional logit framework, while it increases by up to 29 percent in the Poisson model. Policy makers ought not to ignore a difference of such magnitude.

4 Conclusions

We show that the three standard location choice models - conditional logit, nested logit and Poisson - are observationally equivalent in terms of cross-section estimation yet imply starkly different predictions.

Take a corporate tax cut in a particular region. Provided that this is perceived by firms as making that region more attractive, all three models imply that the region itself will see an increase in its number of firms. We show that the magnitude of the implied increase differs: it is largest if the world is properly represented by the Poisson model, smallest if the world conforms with the conditional logit, and somewhere in-between if the world is nested logit. In a Poisson world, the tax cut will have no impact on firm counts in any other of regions within the data set. It will, however, pull firms away from other regions in the conditional logit and the nested logit cases. As the total number of firms is fixed in the conditional logit, the sum of the firms pulled away from the other regions is the same as the increase in the number

of firms in the tax-cutting region itself. The nested logit again represents an intermediate case, with some of the attracted firms relocating from elsewhere within the data set, implying that regional corporate tax bases are “rival”; and some firms appearing from outside that set, implying a “non-rival” tax base. The same logic can be applied to residential choices of private households with respect, for instance, to changes in local property tax rates.

Empirical researchers should be aware of the interpretational ambiguity affecting estimated parameters in standard location choice models, particularly if the number of locations and industries distinguished in the data is small. It can therefore be useful to report both conditional logit and Poisson elasticity estimates as bounds on the effects implied by the estimated parameters.

References

- [1] Arzaghi, Mohammad and J. Vernon Henderson (2008) Networking off Madison Avenue. *Review of Economic Studies*, 75(4): 1011-1038.
- [2] Bartik, Timothy J. (1985) Business Location Decisions in the United States: Estimates of the Effects of Unionization, Taxes and Other Characteristics of States. *Journal of Business and Economic Statistics*, 3(1): 14-22.
- [3] Bayer, Patrick; Fernando Ferreira and Robert McMillan (2007) A Unified Framework for Measuring Preferences for Schools and Neighborhoods. *Journal of Political Economy*, 115(4): 588-638.
- [4] Becker, Randy and Vernon Henderson (2000) Effects of Air Quality Regulations on Polluting Industries. *Journal of Political Economy*, 108(2): 379-421.
- [5] Börsch-Supan, Axel (1990) Education and its Double-Edged Impact on Mobility. *Economics of Education Review*, 9(1): 39-53.
- [6] Brühlhart, Marius; Mario Jametti and Kurt Schmidheiny (2007) Do Agglomeration Economies Reduce the Sensitivity of Firm Location to Tax Differentials? *CEPR Discussion Paper #6609*.
- [7] Carlton, Dennis W. (1983) The Location and Employment Choices of New Firms: An Econometric Model with Discrete and Continuous Endogenous Variables. *Review of Economics and Statistics*, 65: 440-449.
- [8] Chirinko, Robert S. and Daniel J. Wilson (2008) State Investment Tax Incentives: A Zero-Sum Game? *Journal of Public Economics*, 92(12): 2362-2384.
- [9] Coeurdacier, Nicolas; Roberto A. De Santis and Antonin Aviat (2009) Cross-Border Mergers and Acquisitions and European Integration. *Economic Policy*, 24(57): 55-106.
- [10] Crozet, Matthieu; Thierry Mayer and Jean-Louis Mucchielli (2004) How Do Firms Agglomerate? A Study of FDI in France. *Regional Science and Urban Economics*, 34(1): 27-54.
- [11] Davis, James C. and J. Vernon Henderson (2008) The Agglomeration of Headquarters. *Regional Science and Urban Economics*, 38(5): 445-460.
- [12] Devereux, Michael P.; Rachel Griffith and Helen Simpson (2007) Firm Location Decisions, Regional Grants and Agglomeration Externalities. *Journal of Public Economics*, 91(3-4): 413-435.

- [13] Duranton, Gilles; Laurent Gobillon and Henry G. Overman (2006) Assessing the Effects of Local Taxation Using Microgeographic Data. *CEPR Discussion Paper #5856*.
- [14] Ellickson, Bryan (1981) An Alternative Test of the Hedonic Theory of Housing Markets. *Journal of Urban Economics*, 9(1): 56-79.
- [15] Flowerdew, Robin and Murray Aitkin (1982) A Method of Fitting the Gravity Model Based on the Poisson Distribution. *Journal of Regional Science*, 22(2): 191-202.
- [16] Greenstone, Michael and Enrico Moretti (2003) Bidding for Industrial Plants: Does Winning a ‘Million Dollar Plant’ Increase Welfare? *NBER Working Paper #9844*.
- [17] Guimaraes, Paulo; Octávio Figueiredo and Douglas Woodward (2000) Agglomeration and the Location of Foreign Direct Investment in Portugal. *Journal of Urban Economics*, 47(1): 115-135.
- [18] Guimaraes, Paulo; Octávio Figueiredo and Douglas Woodward (2003) A Tractable Approach to the Firm Location Decision Problem. *Review of Economics and Statistics*, 85(1): 201-204.
- [19] Guimaraes, Paulo; Octávio Figueiredo and Douglas Woodward (2004) Industrial Location Modelling: Extending the Random Utility Framework. *Journal of Regional Science*, 44(1): 1-20.
- [20] Head, Keith and Thierry Mayer (2004) Market Potential and the Location of Japanese Investment in the European Union. *Review of Economics and Statistics*, 86(2): 959-972.
- [21] Head, Keith; John Ries and Deborah L. Swenson (1995) Agglomeration Benefits and Location Choice: Evidence from Japanese Manufacturing Investment in the United States. *Journal of International Economics*, 38(3-4): 223-247.
- [22] Holl, Adelheid (2004) Manufacturing Location and Impacts of Road Transport Infrastructure: Empirical Evidence from Spain. *Regional Science and Urban Economics*, 34(3): 341-363.
- [23] List, John A. (2001) US County-Level Determinants of Inbound FDI: Evidence from a Two-Step Modified Count Data Model. *International Journal of Industrial Organization*, 19: 953-973.
- [24] McFadden, Daniel (1974) Conditional Logit Analysis of Qualitative Choice Behavior. In P. Zarembka (ed.) *Frontiers in Econometrics*, New York: Academic Press, 105-142.
- [25] McFadden, Daniel (1978), Modelling the Choice of Residential Location. In A. Karlqvist et al. (ed.) *Spatial Interaction Theory and Planning Models*, Amsterdam: North-Holland.
- [26] Nechyba, Thomas J. and Robert P. Strauss (1998) Community Choice and Local Public Services: A Discrete Choice Approach. *Regional Science and Urban Economics*, 28(1): 51-73.
- [27] Papke, Leslie E. (1991) Interstate Business Tax Differentials and New Firm Location: Evidence from Panel Data. *Journal of Public Economics*, 45(1): 47-68.
- [28] Quigley, John M. (1985) Consumer Choice of Dwelling, Neighborhood and Public Services. *Regional Science and Urban Economics*, 15(1): 41-63.
- [29] Schmidheiny, Kurt (2006) Income Segregation and Local Progressive Taxation: Empirical Evidence from Switzerland. *Journal of Public Economics*, 90(3): 429-458.
- [30] Wilson, Daniel J. (2009) beggar thy Neighbor? The In-State, Out-of-State, and Aggregate Effects of R&D Tax Credits. *Review of Economics and Statistics*, 91(2): 431-436.

Appendix: Derivations for case B

Grouped conditional logit

The conditional logit model for *grouped data* is given by the probability that a given firm f of industry s chooses region j

$$P_{j|f} = P_{j|s} = \frac{e^{x'_{sj}\beta}}{\sum_{i=1}^J e^{x'_{si}\beta}}.$$

The log likelihood function is

$$\log L(\beta) = \sum_{s=1}^S \sum_{j=1}^J N_{sj} P_{j|s} = \sum_{s=1}^S \left\{ \sum_{j=1}^J N_{sj} x'_{sj}\beta - \sum_{j=1}^J [N_{sj} \log \sum_{i=1}^J e^{x'_{si}\beta}] \right\}.$$

The expected number of firms in region j and industry s is

$$E(n_{sj}) = n_s P_{j|s} = \frac{n_s e^{x'_{sj}\beta}}{\sum_{i=1}^J e^{x'_{si}\beta}}.$$

and the corresponding own-region and cross-region elasticities within industry s are, respectively,

$$\begin{aligned} \frac{\partial \log E(n_{sj})}{\partial x_{sjk}} &= (1 - P_{j|s})\beta_k, \\ \frac{\partial \log E(n_{si})}{\partial x_{sjk}} &= -P_{j|s}\beta_k. \end{aligned}$$

The expected number of firms in industry s is

$$E(n_s) = \sum_{j=1}^J E(n_{sj}) = n_s = N_s,$$

and the corresponding elasticity within industry s is

$$\frac{\partial \log E(n_s)}{\partial x_{sjk}} = 0.$$

The expected number of firms in region j is

$$E(n_j) = \sum_{s=1}^S E(n_{sj}) = \sum_{s=1}^S n_s P_{j|s} = \sum_{s=1}^S \frac{n_s e^{x'_{sj}\beta}}{\sum_{i=1}^J e^{x'_{si}\beta}}.$$

The corresponding own-region and cross-region elasticities are for a region-industry specific shock x_{sjk} are

$$\begin{aligned} \frac{\partial \log E(n_j)}{\partial x_{sjk}} &= \frac{\partial \log E(n_{sj})}{\partial x_{sjk}} \cdot \frac{E(n_{sj})}{E(n_j)} = (1 - P_{j|s})P_{s|j}\beta_k, \\ \frac{\partial \log E(n_i)}{\partial x_{sjk}} &= \frac{\partial \log E(n_{si})}{\partial x_{sjk}} \cdot \frac{E(n_{si})}{E(n_i)} = -P_{j|s}P_{s|i}\beta_k, \end{aligned}$$

where $P_{s|j} = E(n_{sj})/E(n_j)$.

The own-region and cross-region elasticities for a region-specific shock x_{jk} are

$$\frac{\partial \log E(n_j)}{\partial x_{jk}} = \sum_{s=1}^S \left[\frac{\partial \log E(n_{sj})}{\partial x_{jk}} \cdot \frac{E(n_{sj})}{E(n_j)} \right] = \beta_k \sum_{s=1}^S (1 - P_{j|s})P_{s|j},$$

$$\frac{\partial \log E(n_i)}{\partial x_{jk}} = \sum_{s=1}^S \left[\frac{\partial \log E(n_{si})}{\partial x_{jk}} \cdot \frac{E(n_{si})}{E(n_i)} \right] = -\beta_k \sum_{s=1}^S P_{j|s} P_{s|i}.$$

The expected total number of firms in all regions and industries is

$$E(n) = \sum_{s=1}^S \sum_{j=1}^J E(n_{js}) = \sum_{s=1}^S E(n_s) = n,$$

and the corresponding elasticities for a region-industry specific shock x_{sjk} and a region-specific shock x_{jk} are, respectively,

$$\begin{aligned} \frac{\partial \log E(n)}{\partial x_{sjk}} &= 0, \\ \frac{\partial \log E(n)}{\partial x_{jk}} &= 0. \end{aligned}$$

Grouped Poisson

The Poisson model for grouped data is given as

$$E(n_{sj}) = \lambda_{sj} = e^{\alpha_s + x'_{sj}\beta},$$

where α_s is an industry-specific constant. The concentrated log likelihood function is

$$\log L(\beta) = \sum_{s=1}^S \left\{ \sum_{j=1}^J N_{sj} x'_{sj}\beta - \sum_{j=1}^J [N_{sj} \log(\sum_{i=1}^J e^{x'_{si}\beta})] - \sum_{j=1}^J \log N_{sj}! + N_s \log N_s \right\} - N.$$

The share of firms in region j for any given industry s is given by

$$P_{j|s} = \frac{E(n_{sj})}{\sum_{i=1}^J E(n_{si})} = \frac{e^{\alpha_s + x'_{sj}\beta}}{\sum_{i=1}^J e^{\alpha_s + x'_{si}\beta}} = \frac{e^{x'_{sj}\beta}}{\sum_{i=1}^J e^{x'_{si}\beta}}.$$

The own-region and cross-region elasticities within industry s are, respectively,

$$\begin{aligned} \frac{\partial \log E(n_{sj})}{\partial x_{sjk}} &= \beta_k, \\ \frac{\partial \log E(n_{si})}{\partial x_{sjk}} &= 0. \end{aligned}$$

The expected number of firms in industry s is

$$E(n_s) = \sum_{i=1}^J E(n_{si}) = \sum_{i=1}^J e^{\alpha_s + x'_{si}\beta} = \sum_{i=1}^J E(n_{si}) = \sum_{i=1}^J e^{\alpha_s + x'_{si}\beta} = e^{\alpha_s} \sum_{i=1}^J e^{x'_{si}\beta},$$

and the corresponding elasticity within industry s is

$$\frac{\partial \log E(n_s)}{\partial x_{sjk}} = \frac{e^{x'_{sj}\beta}}{\sum_{i=1}^J e^{x'_{si}\beta}} \beta_k = P_{j|s} \beta_k.$$

The expected number of firms in region j is

$$E(n_j) = \sum_{s=1}^S E(n_{sj}) = \sum_{s=1}^S e^{\alpha_s + x'_{sj}\beta}.$$

The corresponding own-region and cross-region elasticities for a region-industry specific shock

x_{sjk} are

$$\begin{aligned}\frac{\partial \log E(n_j)}{\partial x_{sjk}} &= \frac{\partial \log E(n_{sj})}{\partial x_{sjk}} \cdot \frac{E(n_{sj})}{E(n_j)} = P_{s|j} \beta_k, \\ \frac{\partial \log E(n_i)}{\partial x_{sjk}} &= \frac{\partial \log E(n_{si})}{\partial x_{sjk}} \cdot \frac{E(n_{si})}{E(n_i)} = 0,\end{aligned}$$

where $P_{s|j} = E(n_{sj})/E(n_j)$.

The own-region and cross-region elasticities for a region-specific shock x_{jk} are

$$\begin{aligned}\frac{\partial \log E(n_j)}{\partial x_{jk}} &= \sum_{s=1}^S \left[\frac{\partial \log E(n_{sj})}{\partial x_{jk}} \cdot \frac{E(n_{sj})}{E(n_j)} \right] = \beta_k, \\ \frac{\partial \log E(n_i)}{\partial x_{jk}} &= \sum_{s=1}^S \left[\frac{\partial \log E(n_{si})}{\partial x_{jk}} \cdot \frac{E(n_{si})}{E(n_i)} \right] = 0.\end{aligned}$$

The expected total number of firms in all regions and industries is

$$E(n) = \sum_{s=1}^S \sum_{j=1}^J E(n_{js}) = \sum_{s=1}^S E(n_s) = \sum_{s=1}^S \left[e^{\alpha_s} \sum_{i=1}^J e^{x'_{si}\beta} \right],$$

and the corresponding elasticities for a region-industry specific shock x_{sjk} and a region-specific shock x_{jk} are, respectively,

$$\begin{aligned}\frac{\partial \log E(n)}{\partial x_{sjk}} &= \frac{\partial \log E(n_{sj})}{\partial x_{sjk}} \cdot \frac{E(n_{sj})}{E(n)} = P_{s|j} P_j \beta_k, \\ \frac{\partial \log E(n)}{\partial x_{jk}} &= \frac{\partial \log E(n_j)}{\partial x_{jk}} \cdot \frac{E(n_j)}{E(n)} = P_j \beta_k,\end{aligned}$$

where $P_j = E(n_j)/E(n)$.

Grouped nested logit

The nested logit model for *grouped data* is given by the probability that firm f of industry s chooses the outside option $j = 0$ or region $j > 0$:

$$\begin{aligned}P_{0|s} &= \frac{e^{\delta_s}}{e^{\delta_s} + (\sum_{j=1}^J e^{x'_{sj}\gamma/\lambda})^\lambda} = \frac{e^{\delta_s}}{e^{\delta_s} + (\sum_{j=1}^J e^{x'_{sj}\beta})^\lambda}, \\ P_{j|s} &= \frac{e^{x'_{sj}\beta} (\sum_{i=1}^J e^{x'_{si}\beta})^{\lambda-1}}{e^{\delta_s} + (\sum_{i=1}^J e^{x'_{si}\beta})^\lambda} = P_{j>0|s} \cdot P_{j|j>0,s} = (1 - P_{0|s}) P_{j|j>0,s},\end{aligned}$$

where δ_s is an industry-specific constant, $\beta = \gamma/\lambda$ and

$$P_{j|j>0,s} = \frac{e^{x'_{sj}\beta}}{\sum_{i=1}^J e^{x'_{si}\beta}}.$$

The concentrated log likelihood function is

$$\begin{aligned}\log L(\beta) &= \sum_{s=1}^S \left\{ \sum_{j=1}^J N_{sj} x'_{sj} \beta - \sum_{j=1}^J [N_{sj} \log \sum_{i=1}^J e^{x'_{si}\beta}] \right. \\ &\quad \left. + N_{s0} \log(N_{s0}) + N_s \log(N_s) - (N_s + N_{s0}) \log(N_s + N_{s0}) \right\}.\end{aligned}$$

The expected number of firms in domestic region $j > 0$ and industry s is

$$E(n_{sj}) = (n_s + n_{s0}) P_{j|s} = (n_s + n_{s0}) (1 - P_{0|s}) P_{j|j>0,s},$$

and the corresponding own-region and cross-region elasticities within industry s are, respectively,

$$\begin{aligned}\frac{\partial \log E(n_{sj})}{\partial x_{sjk}} &= [1 - P_{j|j>0,s}(1 - \lambda P_{0|s})]\beta_k, \\ \frac{\partial \log E(n_{si})}{\partial x_{sjk}} &= -P_{j|j>0,s}(1 - \lambda P_{0|s})\beta_k.\end{aligned}$$

The expected number of all domestic firms in industry s is

$$E(n_s) = \sum_{j=1}^J E(n_{sj}) = (n_s + n_{s0})(1 - P_{0|s}),$$

and the corresponding elasticity within industry s is

$$\frac{\partial \log E(n_s)}{\partial x_{sjk}} = \lambda P_{0|s} P_{j|j>0,s} \beta_k.$$

The expected number of firms in domestic region j is

$$E(n_j) = \sum_{s=1}^S E(n_{sj}) = \sum_{s=1}^S (n_s + n_{s0}) P_{j|s}.$$

The corresponding own-region and cross-region elasticities for a region-industry specific shock x_{sjk} are

$$\begin{aligned}\frac{\partial \log E(n_j)}{\partial x_{sjk}} &= \frac{\partial \log E(n_{sj})}{\partial x_{sjk}} \cdot \frac{E(n_{sj})}{E(n_j)} = [1 - P_{j|j>0,s}(1 - \lambda P_{0|s})] P_{s|j} \beta_k, \\ \frac{\partial \log E(n_i)}{\partial x_{sjk}} &= \frac{\partial \log E(n_{si})}{\partial x_{sjk}} \cdot \frac{E(n_{si})}{E(n_i)} = -P_{j|j>0,s}(1 - \lambda P_{0|s}) P_{s|i} \beta_k,\end{aligned}$$

where $P_{s|j} = E(n_{sj})/E(n_j)$.

The own-region and cross-region elasticities for a region-specific shock x_{jk} are

$$\begin{aligned}\frac{\partial \log E(n_j)}{\partial x_{jk}} &= \sum_{s=1}^S \left[\frac{\partial \log E(n_{sj})}{\partial x_{jk}} \cdot \frac{E(n_{sj})}{E(n_j)} \right] = \beta_k \sum_{s=1}^S [1 - P_{j|j>0,s}(1 - \lambda P_{0|s})] P_{s|j}, \\ \frac{\partial \log E(n_i)}{\partial x_{jk}} &= \sum_{s=1}^S \left[\frac{\partial \log E(n_{si})}{\partial x_{jk}} \cdot \frac{E(n_{si})}{E(n_i)} \right] = -\beta_k \sum_{s=1}^S P_{j|j>0,s}(1 - \lambda P_{0|s}) P_{s|i}.\end{aligned}$$

The expected total number of firms in all domestic regions and industries is

$$E(n) = \sum_{s=1}^S \sum_{j=1}^J E(n_{js}) = \sum_{j=1}^J E(n_j),$$

and the corresponding elasticities for a region-industry specific shock x_{sjk} and a region-specific shock x_{jk} are, respectively,

$$\begin{aligned}\frac{\partial \log E(n)}{\partial x_{sjk}} &= \left[\frac{\partial \log E(n_{sj})}{\partial x_{sjk}} + \sum_{i \neq j, i > 0} \frac{\partial \log E(n_{si})}{\partial x_{sjk}} \right] \cdot \frac{E(n_{sj})}{E(n)} = \beta_k \lambda P_{0|s} P_{s|j} P_j, \\ \frac{\partial \log E(n)}{\partial x_{jk}} &= \left[\frac{\partial \log E(n_j)}{\partial x_{jk}} + \sum_{i \neq j, i > 0} \frac{\partial \log E(n_i)}{\partial x_{jk}} \right] \cdot \frac{E(n_j)}{E(n)} = \beta_k P_j \sum_{s=1}^S (\lambda P_{0|s} P_{s|j}),\end{aligned}$$

where $P_j = E(n_j)/E(n)$.

CESifo Working Paper Series

for full list see www.cesifo-group.org/wp

(address: Poschingerstr. 5, 81679 Munich, Germany, office@cesifo.de)

- 2661 Oliver Falck, Stephan Heblich and Elke Luedemann, Identity and Entrepreneurship, May 2009
- 2662 Christian Lessmann and Gunther Markwardt, One Size Fits All? Decentralization, Corruption, and the Monitoring of Bureaucrats, May 2009
- 2663 Felix Bierbrauer, On the Legitimacy of Coercion for the Financing of Public Goods, May 2009
- 2664 Alessandro Cigno, Agency in Family Policy: A Survey, May 2009
- 2665 Claudia M. Buch and Christian Pierdzioch, Low Skill but High Volatility?, May 2009
- 2666 Hendrik Jürges, Kerstin Schneider, Martin Senkbeil and Claus H. Carstensen, Assessment Drives Learning: The Effect of Central Exit Exams on Curricular Knowledge and Mathematical Literacy, June 2009
- 2667 Eric A. Hanushek and Ludger Woessmann, Schooling, Cognitive Skills, and the Latin American Growth Puzzle, June 2009
- 2668 Ourania Karakosta, Christos Kotsogiannis and Miguel-Angel Lopez-Garcia, Does Indirect Tax Harmonization Deliver Pareto Improvements in the Presence of Global Public Goods?, June 2009
- 2669 Aleksandra Riedl and Silvia Rocha-Akis, Testing the Tax Competition Theory: How Elastic are National Tax Bases in OECD Countries?, June 2009
- 2670 Dominique Demougin and Carsten Helm, Incentive Contracts and Efficient Unemployment Benefits, June 2009
- 2671 Guglielmo Maria Caporale and Luis A. Gil-Alana, Long Memory in US Real Output per Capita, June 2009
- 2672 Jim Malley and Ulrich Woitek, Productivity Shocks and Aggregate Cycles in an Estimated Endogenous Growth Model, June 2009
- 2673 Vivek Ghosal, Business Strategy and Firm Reorganization under Changing Market Conditions, June 2009
- 2674 Francesco Menoncin and Paolo M. Panteghini, Retrospective Capital Gains Taxation in the Real World, June 2009
- 2675 Thomas Hemmelgarn and Gaëtan Nicodème, Tax Co-ordination in Europe: Assessing the First Years of the EU-Savings Taxation Directive, June 2009

- 2676 Oliver Himmler, The Effects of School Competition on Academic Achievement and Grading Standards, June 2009
- 2677 Rolf Golombek and Michael Hoel, International Cooperation on Climate-Friendly Technologies, June 2009
- 2678 Martin Cave and Matthew Corkery, Regulation and Barriers to Trade in Telecommunications Services in the European Union, June 2009
- 2679 Costas Arkolakis, A Unified Theory of Firm Selection and Growth, June 2009
- 2680 Michelle R. Garfinkel, Stergios Skaperdas and Constantinos Syropoulos, International Trade and Transnational Insecurity: How Comparative Advantage and Power are Jointly Determined, June 2009
- 2681 Marcelo Resende, Capital Structure and Regulation in U.S. Local Telephony: An Exploratory Econometric Study; June 2009
- 2682 Marc Gronwald and Janina Ketterer, Evaluating Emission Trading as a Policy Tool – Evidence from Conditional Jump Models, June 2009
- 2683 Stephan O. Hornig, Horst Rottmann and Rüdiger Wapler, Information Asymmetry, Education Signals and the Case of Ethnic and Native Germans, June 2009
- 2684 Benoit Dostie and Rajshri Jayaraman, The Effect of Adversity on Process Innovations and Managerial Incentives, June 2009
- 2685 Peter Egger, Christian Keuschnigg and Hannes Winner, Incorporation and Taxation: Theory and Firm-level Evidence, June 2009
- 2686 Chrysovalantou Milliou and Emmanuel Petrakis, Timing of Technology Adoption and Product Market Competition, June 2009
- 2687 Hans Degryse, Frank de Jong and Jérémie Lefebvre, An Empirical Analysis of Legal Insider Trading in the Netherlands, June 2009
- 2688 Subhasish M. Chowdhury, Dan Kovenock and Roman M. Sheremeta, An Experimental Investigation of Colonel Blotto Games, June 2009
- 2689 Alexander Chudik, M. Hashem Pesaran and Elisa Tosetti, Weak and Strong Cross Section Dependence and Estimation of Large Panels, June 2009
- 2690 Mohamed El Hedi Arouri and Christophe Rault, On the Influence of Oil Prices on Stock Markets: Evidence from Panel Analysis in GCC Countries, June 2009
- 2691 Lars P. Feld and Christoph A. Schaltegger, Political Stability and Fiscal Policy – Time Series Evidence for the Swiss Federal Level since 1849, June 2009
- 2692 Michael Funke and Marc Gronwald, A Convex Hull Approach to Counterfactual Analysis of Trade Openness and Growth, June 2009

- 2693 Patricia Funk and Christina Gathmann, Does Direct Democracy Reduce the Size of Government? New Evidence from Historical Data, 1890-2000, June 2009
- 2694 Kirsten Wandschneider and Nikolaus Wolf, Shooting on a Moving Target: Explaining European Bank Rates during the Interwar Period, June 2009
- 2695 J. Atsu Amegashie, Third-Party Intervention in Conflicts and the Indirect Samaritan's Dilemma, June 2009
- 2696 Enrico Spolaore and Romain Wacziarg, War and Relatedness, June 2009
- 2697 Steven Brakman, Charles van Marrewijk and Arjen van Witteloostuijn, Market Liberalization in the European Natural Gas Market – the Importance of Capacity Constraints and Efficiency Differences, July 2009
- 2698 Huifang Tian, John Whalley and Yuezhou Cai, Trade Sanctions, Financial Transfers and BRIC's Participation in Global Climate Change Negotiations, July 2009
- 2699 Axel Dreher and Justina A. V. Fischer, Government Decentralization as a Disincentive for Transnational Terror? An Empirical Analysis, July 2009
- 2700 Balázs Égert, Tomasz Koźluk and Douglas Sutherland, Infrastructure and Growth: Empirical Evidence, July 2009
- 2701 Felix Bierbrauer, Optimal Income Taxation and Public Goods Provision in a Large Economy with Aggregate Uncertainty, July 2009
- 2702 Marc Gronwald, Investigating the U.S. Oil-Macroeconomy Nexus using Rolling Impulse Responses, July 2009
- 2703 Ali Bayar and Bram Smeets, Government Deficits in the European Union: An Analysis of Entry and Exit Dynamics, July 2009
- 2704 Stergios Skaperdas, The Costs of Organized Violence: A Review of the Evidence, July 2009
- 2705 António Afonso and Christophe Rault, Spend-and-tax: A Panel Data Investigation for the EU, July 2009
- 2706 Bruno S. Frey, Punishment – and beyond, July 2009
- 2707 Michael Melvin and Mark P. Taylor, The Crisis in the Foreign Exchange Market, July 2009
- 2708 Firouz Gahvari, Friedman Rule in a Model with Endogenous Growth and Cash-in-advance Constraint, July 2009
- 2709 Jon H. Fiva and Gisle James Natvik, Do Re-election Probabilities Influence Public Investment?, July 2009

- 2710 Jarko Fidrmuc and Iikka Korhonen, The Impact of the Global Financial Crisis on Business Cycles in Asian Emerging Economies, July 2009
- 2711 J. Atsu Amegashie, Incomplete Property Rights and Overinvestment, July 2009
- 2712 Frank R. Lichtenberg, Response to Baker and Fugh-Berman's Critique of my Paper, "Why has Longevity Increased more in some States than in others?", July 2009
- 2713 Hans Jarle Kind, Tore Nilssen and Lars Sørgard, Business Models for Media Firms: Does Competition Matter for how they Raise Revenue?, July 2009
- 2714 Beatrix Brügger, Rafael Lalive and Josef Zweimüller, Does Culture Affect Unemployment? Evidence from the Röstigraben, July 2009
- 2715 Oliver Falck, Michael Fritsch and Stephan Heblich, Bohemians, Human Capital, and Regional Economic Growth, July 2009
- 2716 Wladimir Raymond, Pierre Mohnen, Franz Palm and Sybrand Schim van der Loeff, Innovative Sales, R&D and Total Innovation Expenditures: Panel Evidence on their Dynamics, July 2009
- 2717 Ben J. Heijdra and Jochen O. Mierau, Annuity Market Imperfection, Retirement and Economic Growth, July 2009
- 2718 Kai Carstensen, Oliver Hülsewig and Timo Wollmershäuser, Price Dispersion in the Euro Area: The Case of a Symmetric Oil Price Shock, July 2009
- 2719 Katri Kosonen and Gaëtan Nicodème, The Role of Fiscal Instruments in Environmental Policy, July 2009
- 2720 Guglielmo Maria Caporale, Luca Onorante and Paolo Paesani, Inflation and Inflation Uncertainty in the Euro Area, July 2009
- 2721 Thushyanthan Baskaran and Lars P. Feld, Fiscal Decentralization and Economic Growth in OECD Countries: Is there a Relationship?, July 2009
- 2722 Nadia Fiorino and Roberto Ricciuti, Interest Groups and Government Spending in Italy, 1876-1913, July 2009
- 2723 Andreas Wagener, Tax Competition, Relative Performance and Policy Imitation, July 2009
- 2724 Hans Fehr and Fabian Kindermann, Pension Funding and Individual Accounts in Economies with Life-cyclers and Myopes, July 2009
- 2725 Ernesto Reuben and Arno Riedl, Enforcement of Contribution Norms in Public Good Games with Heterogeneous Populations, July 2009
- 2726 Kurt Schmidheiny and Marius Brülhart, On the Equivalence of Location Choice Models: Conditional Logit, Nested Logit and Poisson, July 2009