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My Dissertation

by

Johnny Elvis Bravo

Dissertation presented for the degree of Doctor of Philosophy in Economics in the Faculty of Economic and Management Sciences at Stellenbosch University

Supervisor: Prof. F. Flintstone

April 2025

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Declaration

By submitting this dissertation electronically, I declare that the entirety of the work contained therein is my own, original work, that I am the sole author thereof (save to the extent explicitly otherwise stated), that reproduction and publication thereof by Stellenbosch University will not infringe any third party rights and that I have not previously in its entirety or in part submitted it for obtaining any qualification.

Date: 30th July 2024 .....

Abstract

My Dissertation

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Dissertation: PhD (Economics)

April 2025

In this dissertation...

Our results show...

Uittreksel

My Proefskrif

(“My Dissertation”)

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Proefskrif: PhD (Ekonomie)

April 2025

In hierdie proefskrif...

Ons resultate dui aan...

Acknowledgements

I would like to express my sincere gratitude to the following people:

- My supervisor...
- My family...

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Nomenclature

Variables

θ	elasticity of demand
$distance$	population-weighted distance . . . . . [km]

Vectors

$\boldsymbol{\beta}'\boldsymbol{w}_{idt}$	set of gravity covariates

Subscripts

i	importer
j	exporter
t	period

Acronyms

MNO	mobile network operator
OLS	ordinary least squares
PPML	Poisson Pseudo-Maximum Likelihood

Chapter 1

Heading level 1

This is an R Markdown (`.Rmd`) document. Markdown is a simple formatting syntax for authoring HTML, PDF, and MS Word documents. For more details on using R Markdown see this link.

When you click the **Knit** button (or `Ctrl + Shift + K`) a document will be generated that includes both content as well as the output of any embedded R code chunks within the document. You can embed an R code chunk like this (`Ctrl + Alt + I`):

```
summary(cars)
```

```
##      speed           dist
##  Min.   : 4.0   Min.   :  2.00
##  1st Qu.:12.0   1st Qu.: 26.00
##  Median :15.0   Median : 36.00
##  Mean   :15.4   Mean   : 42.98
##  3rd Qu.:19.0   3rd Qu.: 56.00
##  Max.   :25.0   Max.   :120.00
```

Note that the `echo = T` parameter was added to the code chunk to print the R code that generated the output. By default, this is set to `echo = F`. Code chunk default options are set in `knitr::opts_chunk$set(...)` in the chunk above called `setup`. Learn more about code chunk options at this link.

1.1 Heading level 2

Prevent header numbering with `{-}`, e.g., `# Header level 1 {-}` or `## Header level 2 {-}` and so on.

1.1.1 Heading level 3

With `source()`, you can load scripts of code stored elsewhere in your directory. In the example below, all custom functions stored in `code/functions.R` are loaded, e.g., the `hello_function()` which prints the name stored in the YAML metadata. It may be worthwhile to run `source("code/functions.R", local = knitr::knit_global())` in your setup chunk, making your own functions accessible throughout your `.Rmd` document.

```
source("code/functions.R", local = knitr::knit_global())
hello_function()
```

```
## Hallo Johnny Elvis Bravo! This a sourced function.
```

Chapter 2

Useful Commands

2.1 Lists

Itemized lists can be created using Markdown syntax like this:

- Item 1
- Item 2
- Item 3

Numbered lists can be created using Markdown syntax like this:

1. Item 1
2. Item 2
3. Item 3

These are equivalent to using the LaTeX syntax:

```
\begin{itemize} % or enumerate
\item Item 1
\item Item 2
\item Item 3
\end{itemize} % or enumerate
```

2.2 References and Citations

The bibliography file can be found in `matter/mybib.bib`. Bibliography entries are stored in the `bibtex` format. Each entry is associated with a unique key, e.g., "anderson_etal16". The citation package is set to `natbib`.

- `\citet{key}`: Textual citation, e.g., Anderson et al. (2016)
- `\citep{key}`: Parenthetical citation, e.g., (Anderson et al., 2016)
- `\citet*{key}`: Same as \citet but if there are several authors, all names are printed, e.g., Anderson, Vesselovsky, and Yotov (2016)
- `\citep*{key}`: The same as \citep but if there are several authors, all names are printed, e.g., (Anderson, Vesselovsky, and Yotov, 2016)
- `\citeauthor{key}`: Prints only the name of the authors(s), e.g., Anderson et al.
- `\citeyear{key}`: Prints only the year of the publication, e.g., 2016

Citations can also be made using Markdown syntax:

- `@key`: Textual citation, e.g., Anderson and Van Wincoop (2003)
- `[@key]`: Parenthetical citation, e.g., (Anderson and Van Wincoop, 2003)
- `-@key`: Parenthetical citation of year, e.g., (2003)

2.3 Abbreviations

- `\ac{PPML}` produces Poisson Pseudo-Maximum Likelihood (PPML) the first time, and PPML the second time.
- `\acf{OLS}` produces ordinary least squares (OLS) and `\acs{OLS}` produces OLS.
- `\Acp{MNO}` produces Mobile network operators (MNOs) and `\acp{MNO}` produces MNOs (the second time).

2.4 Footnotes

Footnotes are created with `\footnote{}` using LaTeX or `^[]` using Markdown. See this example.[1]

2.5 Equations

Equations are constructed with the help of the LaTeX package `amsmath`. An equation must read like part of the text. Use a full stop after the equation to indicate the end of the sentence:

$$e^{i\theta} = \cos\theta + i\sin\theta. \tag{2.1}$$

If the equation is in the middle of the sentence, end the equations with a comma. Then subsequent text should start with lower case. For example, Euler's identity is

$$e^{i\pi} + 1 = 0,$$

where e is Euler's number, the base of natural logarithms.

Here is another pair of equations, this time using `&` to align multiple lines:

$$a^2 + b^2 = c^2 \tag{2.2}$$

$$e^{i\pi} + 1 = 0 \tag{2.3}$$

In the `subequations` LaTeX environment, a series of equations that should share a common number. It only affects the numbering of numbered equations that are within it. In the `gather` LaTeX environment, several displayed equations are typeset after one another. Using these environments together it produces, for

[1] This is an example of a footnote.

example:

$$\frac{\partial \rho}{\partial t} + \frac{\partial}{\partial x_j}\left[\rho u_j\right] = 0 \tag{2.4a}$$

$$\frac{\partial}{\partial t}\left(\rho u_i\right) + \frac{\partial}{\partial x_j}\left[\rho u_i u_j + p\delta_{ij} - \tau_{ji}\right] = 0, \quad i = 1, 2, 3 \tag{2.4b}$$

$$\frac{\partial}{\partial t}\left(\rho e_0\right) + \frac{\partial}{\partial x_j}\left[\rho u_j e_0 + u_j p + q_j - u_i \tau_{ij}\right] = 0 \tag{2.4c}$$

Markdown syntax can also be used. Here is an equation created with a pair of `$$`, which is useful to observe a preview of the equation in your `.Rmd` document prior to knitting:

$$f_X(x) = \left(\frac{\alpha}{\beta}\right)\left(\frac{x}{\beta}\right)^{\alpha-1} e^{-\left(\frac{x}{\beta}\right)^{\alpha}}; \alpha, \beta, x > 0.$$

Inline equations are created with a pair of `$`: $\sum_{i=2}^{\infty}\{\alpha_i^{\beta}\}$

2.6 Symbols

Symbols that represent values of properties should be printed in italics, but SI units and names of functions (e.g. sin, cos and tan) must not be printed in italics. There must be a small hard space between a number and its unit, e.g. 120 km. Use the `siunitx` package to typeset numbers, angles and quantities with units:

`\num{1.23e3}` → 1.23×10^3
`\ang{30}` → 30°
`\qty{20}{N.m}` → 20 N·m

2.7 Other

- `\paragraph{title}`
- `\pagebreak`
- `\clearpage`

Chapter 3

Figures and Tables

The `figure` and `table` environments are floating environments. Floats are containers for things that cannot be broken over a page, such as tables and figures. LaTeX places figures and tables where it deems it befitting. The behavior can be controlled by different placement specifiers and code chunk options such as `fig.pos = "H"`. Below is a list of possible specifiers:

- `h`: Place the float *here*, i.e., approximately at the same point in the source text.
- `t`: Position at the *top* of the page.
- `b`: Position at the *bottom* of the page.
- `p`: Put on a special *page* for floats only.
- `!`: Override LaTeX's internal parameters for determining "good" positions.
- `H`: Place the float at precisely the location in the LaTeX code.

These specifiers can be used in conjunction, e.g., `!b` forces LaTeX to place the figure at the bottom of a page. The default behavior is `htbp`.

Create plots with, e.g., the `ggplot` package from `tidyverse`, using a code chunk like the one below. The resulting plot will be automatically embedded in the document.

Figures can also be included with `knitr::include_graphics`. It relies on the `graphicx` package to import `PDF`, `PNG` or `JPG` graphic files.

```
knitr::include_graphics("figures/waterplants.jpg")
```

Figure 3.2 Water plants

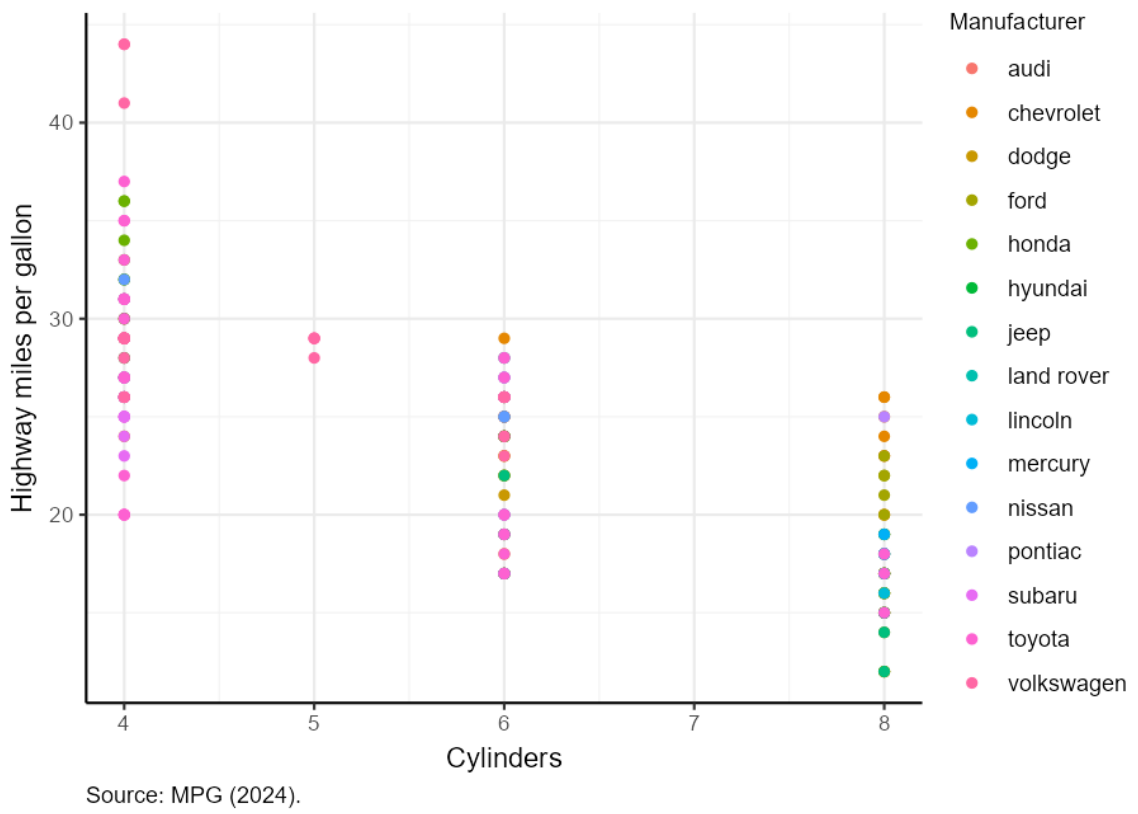

Figure 3.1 Manufacturer fuel efficiency

I recommend using `kbl` and `kable_styling` from the `kableExtra` package for the creation of tables.

```
head(mtcars)[,1:4] %>%
  kbl(digits = 2,
      booktabs = T,
      linesep = "",
      centering = T,
      position = "H",
      escape = T,
      caption = "Caption centered above table") %>%
  kable_styling(font_size = 10) %>%
  footnote(general_title = "Note:",
           general = "This is my table footnote.")
```

Table 3.1 Caption centered above table

	mpg	cyl	disp	hp
Mazda RX4	21.0	6	160	110
Mazda RX4 Wag	21.0	6	160	110
Datsun 710	22.8	4	108	93
Hornet 4 Drive	21.4	6	258	110
Hornet Sportabout	18.7	8	360	175
Valiant	18.1	6	225	105

Note:
This is my table footnote.

Chapter 4

Cross-referencing

- `\label{key}` and `\ref{key}`
- Label individual equations with `\label{key}`
- Prevent numbering of individual equations with `\notag`
- Reference equations with `\eqref{key}`, `\cref{key}` or `\ref{key}`, e.g.:
  - `\eqref{eq:Euler1}` produces (2.1)
  - `\cref{eq:Euler1}` produces Equation (2.1)
  - `\ref{eq:Euler1}` produces 2.1

Chapter 5

Conclusion

Adipiscing condimentum eleifend tellus phasellus eros curae; duis feugiat. Ac tincidunt luctus, justo dictumst dictumst morbi mauris felis ullamcorper massa fringilla. Senectus aenean montes facilisi, vel sapien felis netus laoreet! Id pretium arcu libero turpis dictumst ad tortor. Convallis scelerisque ligula eget nisi – mus lobortis arcu ac himenaeos? Erat rhoncus suscipit hac dictumst taciti, ut erat pharetra leo nam metus sociosqu inceptos nec arcu.

Lorem curae nullam aenean luctus vivamus magna inceptos neque malesuada? Cras vestibulum quisque porttitor molestie aliquet varius ligula mauris dictum! Commodo malesuada aliquam integer; quam pellentesque potenti donec rhoncus at. Magna augue semper, fames facilisi rutrum bibendum nisi. Vel aptent sodales potenti ullamcorper mollis leo phasellus auctor in mattis. Odio cum integer nibh interdum justo felis posuere? Libero magnis per a sapien ullamcorper sollicitudin sollicitudin cursus; ligula varius conubia placerat leo eros magna bibendum.

Lorem nullam cras scelerisque malesuada dis, a tellus at litora ornare diam. Himenaeos nascetur posuere dictumst, nam integer – enim fames nullam. Ultrices ad donec curabitur magna aenean aptent senectus dis? Nibh phasellus sapien turpis, nulla phasellus nunc. Dignissim curabitur aliquam auctor per: sagittis, augue nam ridiculus! Potenti est interdum, pharetra egestas a rutrum ultricies vulputate primis quis natoque commodo pretium maecenas consequat bibendum lobortis.

Dolor erat a torquent magnis: fusce risus dictum rhoncus viverra. Mattis praesent dis suspendisse aenean condimentum vivamus nam molestie ut.

Sit eu potenti curae luctus varius ut congue. Aliquam accumsan ultrices lacinia massa in turpis mauris?

Consectetur fusce mattis hac mollis etiam urna, porttitor non nec. Fames fusce pharetra erat, risus sociosqu – aenean ut fames scelerisque. Curae enim habitant, vitae risus lectus potenti.

Lorem consequat magna netus molestie est, senectus platea pretium tincidunt! Odio pretium convallis dapibus auctor tempor velit aptent ridiculus pretium diam ad. Volutpat vulputate montes metus suscipit taciti – quisque, turpis suspendisse eu? Vulputate nunc aenean ornare!

Dolor faucibus quisque velit semper aptent ullamcorper molestie. Nascetur ultrices penatibus conubia, fusce leo vitae nec luctus et? Fermentum pharetra penatibus eu viverra rutrum eleifend eu: hac egestas, ligula, neque dapibus quam felis libero.

Amet tellus fames sollicitudin tellus viverra duis metus? Enim accumsan netus facilisi hendrerit venenatis eu ut vel!

Sit venenatis varius ligula sollicitudin erat aliquam vehicula semper, aptent quis. Mi nulla magna, parturient phasellus quis at. Ultricies odio pulvinar praesent id ridiculus malesuada, vulputate lacinia vitae platea platea porta! Nam pellentesque sed aliquam venenatis penatibus, vel mus leo sapien. Iaculis in pretium.

Lorem turpis senectus sociosqu morbi vel blandit porta dui. Convallis fusce pharetra ligula eu quis dictumst sociis viverra libero mus metus. Cum odio duis est aptent facilisi bibendum torquent viverra! Molestie vitae diam consequat, penatibus mauris habitasse! Rhoncus blandit convallis, fringilla purus convallis semper lacinia. Dictumst lacinia sodales rhoncus, vestibulum malesuada sem proin, pharetra, fringilla ultricies fames tempus luctus faucibus.

Amet condimentum auctor per volutpat quisque libero, mollis dapibus proin per suscipit. Imperdiet maecenas integer molestie scelerisque, tempus purus ornare quam fringilla laoreet.

Adipiscing nullam consequat porttitor vel natoque condimentum magna quis! Ac dictumst hendrerit donec vulputate nostra malesuada? Suscipit dui ligula pulvinar vehicula aenean cras, faucibus: montes nascetur curabitur? Ante neque senectus tempus arcu molestie turpis rutrum per. Platea odio curabitur rutrum fames facilisis nostra vulputate, purus natoque at dictumst

Appendix A

Mathematics

An inversion formula: Let $g : \mathbb{R}^+ \to \mathbb{R}$ be bounded and right continuous, and let $\varphi(\alpha) := \int_0^\infty e^{-\alpha t} g(t)\, dt$ denote its Laplace transform. Then, for every $t > 0$,

$$g(t) = \lim_{\varepsilon \to 0} \lim_{\lambda \to \infty} \varepsilon^{-1} \sum_{\lambda t < k \le (\lambda+\varepsilon)t} \frac{(-1)^k}{k!} \lambda^k \varphi^{(k)}(\lambda). \tag{A.1}$$

Solutions of systems of ODEs: Let $\mathbf{v}(\mathbf{x}, \boldsymbol{\alpha})$ denote a parametrized vector field ($\mathbf{x} \in U$, $\boldsymbol{\alpha} \in A$) where U is a domain in $\mathbb{R}^n$ and the parameter space A is a domain in $\mathbb{R}^m$. We assume that $\mathbf{v}$ is C^k-differentiable as a function of~$(\mathbf{x}, \boldsymbol{\alpha})$, where~$k \ge 2$. Consider a system of differential equations in~U:

$$\mathbf{x} = \mathbf{v}(\mathbf{x}, \boldsymbol{\alpha}), \qquad \mathbf{x} \in U \tag{A.2}$$

Fix an initial point $\mathbf{p}_0$ in the interior of U, and assume $\mathbf{v}(\mathbf{p}_0, \boldsymbol{\alpha}_0) \neq \mathbf{0}$. Then, for sufficiently small t, $|\mathbf{p}-\mathbf{p}_0|$ and $|\boldsymbol{\alpha}-\boldsymbol{\alpha}_0|$, the system~(A.2) has a unique solution $\mathbf{x}_{\boldsymbol{\alpha}}(t)$ satisfying the initial condition $\mathbf{x}_{\boldsymbol{\alpha}}(0) = \mathbf{p}$, and that solution depends differentiably (of class~C^k) on t, $\mathbf{p}$ and $\boldsymbol{\alpha}$.

Stirling's formula:

$$\Gamma(z) \sim e^{-z} z^{z-1/2} \sqrt{2\pi} \left[1 + \frac{1}{12z} + \frac{1}{288z^2} - \frac{139}{51840z^3} + \dots \right], \quad z \to \infty \text{ in } |\arg z| < \pi. \tag{A.3}$$

Bézier curves: Given z_1, z_2, z_3, z_4 in $\mathbb{C}$, define the B'ezier curve with control points z_1, z_2, z_3, z_4 by

$$z(t) := (1-t)^3 z_1 + 3(1-t)^2 t z_2 + 3(1-t) t^2 z_3 + t^3 z_4, \qquad 0 \le t \le 1.$$

Because $(1-t)^3 + 3(1-t)^2 t + 3(1-t)t^2 + t^3 = (1-t+t)^3 = 1$ and all summands are positive for $0 \le t \le 1$, $z(t)$ is a convex combination of the four points~z_k, hence the curve defined by $z(t)$ lies in their convex hull. As t varies from~0 to~1, the curve moves from z_1 to~z_4 with initial direction $z_2 - z_1$ and final direction $z_4 - z_3$.

Maxwell's equations:

$$\mathbf{B}' = -c\nabla \times \mathbf{E}$$
$$\mathbf{E}' = c\nabla \times \mathbf{B} - 4\pi \mathbf{J}.$$

Residue theorem: Let f be analytic in the region G except for the isolated singularities a_1, a_2, ..., a_m. If γ is a closed rectifiable curve in G which does not pass through any of the points a_k and if $\gamma \approx 0$ in G, then

$$\frac{1}{2\pi i}\int_\gamma f = \sum_{k=1}^{m} n(\gamma; a_k)\,\mathrm{Res}(f; a_k).$$

Maximum modulus principle: Let G be a bounded open set in $\mathbb{C}$ and suppose that f is a continuous function on $\bar{G}$ which is analytic in G. Then

$$\max\{|f(z)| : z \in \bar{G}\} = \max\{|f(z)| : z \in \partial G\}.$$

Jacobi's identity: Define the *theta function* ϑ by

$$\vartheta(t) = \sum_{n=-\infty}^{\infty} \exp(-\pi n^2 t), \qquad t > 0.$$

Then

$$\vartheta(t) = t^{-1/2}\vartheta(1/t).$$

Appendix B

Experiments

Sit taciti congue feugiat ultricies est gravida, pharetra non vehicula velit parturient ultricies donec mattis. Iaculis cum vivamus vitae nec, condimentum orci facilisi lacinia sed est tincidunt – bibendum et. Primis bibendum massa; bibendum tortor volutpat, potenti duis eleifend magna. Vel nulla dictumst semper tristique vulputate, sagittis parturient tempus. Consequat taciti himenaeos mattis!

Elit enim rutrum est magna porttitor ridiculus; magna dui tristique hendrerit senectus cum. Curae auctor senectus convallis; accumsan hendrerit – montes semper id condimentum. Taciti rutrum arcu maecenas urna euismod commodo gravida. Donec massa mattis eros id est, nulla purus cum porttitor. Porttitor eget arcu ante.

Sit fringilla nunc malesuada integer quisque bibendum sodales. Proin semper sollicitudin facilisis malesuada curae scelerisque habitant mauris per molestie conubia? Risus libero interdum facilisi nunc eu per sollicitudin: laoreet volutpat.

Ipsum vulputate quis ultrices suspendisse facilisi primis viverra. Feugiat placerat pulvinar eros imperdiet per, a dictum; lectus morbi egestas ridiculus duis? Volutpat natoque penatibus dapibus enim nisi nascetur ligula cursus? Risus a interdum hac fringilla: consequat iaculis, penatibus dis mus justo mattis. Porta gravida montes, facilisis in class ac nec pellentesque. Libero aliquam vivamus, commodo vivamus nisi; ullamcorper dignissim condimentum?

Sit eget cum blandit platea vivamus sociis ut ullamcorper, pellentesque phasellus. Aliquet torquent nunc, vulputate et penatibus laoreet odio at condimentum condimentum facilisi feugiat. Auctor placerat eleifend consequat ridiculus montes augue nunc ligula posuere ullamcorper. Bibendum sollicitudin mollis litora proin euismod turpis.

Amet nostra at erat tristique! Rutrum lacus vivamus parturient lacus tellus montes vehicula mus. Suscipit lacinia, placerat nunc curae posuere lacus mi vulputate natoque sapien. Euismod velit quam, pharetra tempus habitasse proin dignissim curae! Parturient eros sollicitudin dictumst, nibh fusce elementum ornare risus maecenas natoque, lacinia nulla donec.

Lorem at mus odio dictum – nulla conubia sociosqu quam platea. Vivamus donec aliquet dictum leo, ullamcorper – dictum quisque curabitur duis.

Lorem egestas praesent sociosqu, porttitor feugiat mi! Lectus tempor risus volutpat platea cursus, velit at taciti est sociis suspendisse tortor! Sociis et metus himenaeos, ligula fringilla odio ligula!

Elit quam justo magnis quam placerat habitant neque ornare laoreet placerat habitant! Et ornare cubilia et diam placerat posuere; et ridiculus venenatis. Habitasse ad primis praesent venenatis, sociis nec. Fusce viverra bibendum feugiat egestas – ligula leo mauris odio tempus eu. Varius magna sem sed diam facilisi accumsan in faucibus sapien vivamus risus. Cras hac id eget, sodales donec malesuada sociis?

Sit elementum dui hendrerit non: vivamus mus blandit cras sem duis mauris. Sollicitudin pharetra lectus cum fames hac dis vulputate, quisque porta aliquet! Taciti ullamcorper blandit fames placerat velit rhoncus hendrerit pulvinar elementum! Augue scelerisque faucibus libero – mollis fames eu.

Lorem suspendisse cum elementum mollis gravida at congue turpis lobortis. Morbi mauris porttitor magna eu nullam lobortis vivamus dictum purus, varius mi fringilla ligula? Pulvinar ad placerat nec, odio nulla luctus platea ornare. Vel elementum ac ultrices aliquam suspendisse, taciti tincidunt consequat fermentum. Erat sapien tempus ridiculus himenaeos massa potenti ligula nunc dictum! Maecenas aptent eget cursus morbi feugiat montes tempus montes.

Dolor lobortis rutrum at eu vulputate! Eget quis lobortis elementum, neque turpis enim praesent taciti sapien quis vestibulum montes fermentum sodales

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James E Anderson and Eric Van Wincoop. Gravity with Gravitas: A Solution to the Border Puzzle. *American Economic Review*, 93(1):170–192, 2003. doi: 10.1257/000282803321455214.

James E. Anderson, Mykyta Vesselovsky, and Yoto V. Yotov. Gravity with scale effects. *Journal of International Economics*, 100:174–193, 2016. doi: 10.1016/j.jinteco.2016.03.003.