



## UvA-DARE (Digital Academic Repository)

### Estimating diffusion and adoption parameters in networks

*New estimation approaches for the latent-diffusion-observed-adoption model*

Stephan, L.S.

#### Publication date

2021

[Link to publication](#)

#### Citation for published version (APA):

Stephan, L. S. (2021). *Estimating diffusion and adoption parameters in networks: New estimation approaches for the latent-diffusion-observed-adoption model*.

#### General rights

It is not permitted to download or to forward/distribute the text or part of it without the consent of the author(s) and/or copyright holder(s), other than for strictly personal, individual use, unless the work is under an open content license (like Creative Commons).

#### Disclaimer/Complaints regulations

If you believe that digital publication of certain material infringes any of your rights or (privacy) interests, please let the Library know, stating your reasons. In case of a legitimate complaint, the Library will make the material inaccessible and/or remove it from the website. Please Ask the Library: <https://uba.uva.nl/en/contact>, or a letter to: Library of the University of Amsterdam, Secretariat, Singel 425, 1012 WP Amsterdam, The Netherlands. You will be contacted as soon as possible.



Lisa Susanna Stephan

## Estimating diffusion and adoption parameters in networks

This thesis investigates parameter estimation in a widely applicable model of interaction in social networks. The econometric challenge arises from the fact that this interaction is not fully observable. Three distinct estimation methods are proposed to tackle this problem. The properties of the estimators are investigated by means of analytical considerations and Monte Carlo experiments. Furthermore, the estimators are applied to a concrete setting using publicly available data.

Recent years have seen an increase in the availability of data on social networks and the various activities mediated through them. This has generated a need for econometricians to develop or adjust estimation methods to fit the particular requirements of social network models. This thesis hopes to make a contribution to this new strand of research.

Lisa Susanna Stephan holds a double degree in International Economics and Chinese Studies from the University of Tuebingen (Germany). She has worked several years as a microfinance consultant in Senegal and China, before joining the Tinbergen Institute M.Phil. program and thereafter starting her Ph.D. at the University of Amsterdam.

Estimating diffusion and adoption parameters in networks

Lisa Susanna Stephan



# ESTIMATING DIFFUSION AND ADOPTION PARAMETERS IN NETWORKS

New estimation approaches for the  
latent-diffusion-observed-adoption model

ISBN 978-90-361-0653-5

Cover design: Crasborn Graphic Designers bno, Valkenburg a.d. Geul

This book is no. **783** of the Tinbergen Institute Research Series, established through cooperation between Rozenberg Publishers and the Tinbergen Institute. A list of books which already appeared in the series can be found in the back.

# ESTIMATING DIFFUSION AND ADOPTION PARAMETERS IN NETWORKS

New estimation approaches for the  
latent-diffusion-observed-adoption model

ACADEMISCH PROEFSCHRIFT

ter verkrijging van de graad van doctor  
aan de Universiteit van Amsterdam  
op gezag van de Rector Magnificus  
prof. dr. ir. K.I.J. Maex

ten overstaan van een door het College voor Promoties ingestelde  
commissie, in het openbaar te verdedigen  
op dinsdag 18 mei 2021, te 15.00 uur  
door

**Lisa Susanna Stephan**

geboren te Frankfurt am Main

## Promotiecommissie

<b>Promotor:</b>	Prof. dr. F.R. Kleibergen	Universiteit van Amsterdam
<b>Copromotor:</b>	Dr. M.J. van der Leij	Universiteit van Amsterdam
<b>Overige leden:</b>	Prof. dr. H.P. Boswijk	Universiteit van Amsterdam
	Dr. K.J. van Garderen	Universiteit van Amsterdam
	Prof. dr. C.G.H. Diks	Universiteit van Amsterdam
	Prof. dr. C.H. Hommes	Universiteit van Amsterdam
	Prof. dr. T.A.B. Snijders	Rijksuniversiteit Groningen

Faculteit Economie en Bedrijfskunde

# Acknowledgements

During my time as an M.Phil. and thereafter as a Ph.D. student, I have received a tremendous amount of help and support. I am absolutely aware that this is truly exceptional and that without it, I would not have been able to conduct my studies and research in such an enriching and exciting way. As a consequence, I would like to express my deepest gratitude to all those who have helped and guided me along this way.

First and foremost, I am deeply grateful to my supervisor Prof. Dr. Frank R. Kleibergen and my co-supervisor Dr. Marco J. van der Leij for the incommensurable amount of guidance, help and support that they offered to me throughout this project. They provided me with in-depth feedback and always made time for me when I had questions. They helped me organise my research ideas and gave me important inspirations and insights on how to turn them into concrete research projects. Their expertise was crucial for me to narrow down the scope of each project and to situate it in the context of the literature. They also helped me adopt an academic writing style and patiently showed me how to explain my ideas more concisely. They encouraged me when I encountered difficulties and tolerated my mistakes. When I was lost, they helped me see structure and indicated to me how and where to look for solutions. They stood behind me when I was challenged and they provided me with the space to grow as a researcher. Both academically and personally they are role models for me, who I treasure and admire. I would certainly not be where I am now without them and I feel incredibly grateful to have been able to work under their supervision.

I am very grateful to the administrative and support staff at the University of Amsterdam and at the Tinbergen Institute. In particular, Wilma de Kruijf and Arianne de Jong repeatedly spared no effort to accommodate any particular request of mine and to assist me with all sorts of organisational issues regarding my studies, my thesis, my research visit to the US and my subsequent job search. It was great for me to know at all stages of this process that I could count on their assistance should there be any obstacle.

In the framework of my thesis project, I had the opportunity to undertake a six months research visit to Stanford University. This has been an extremely enriching experience, both academically and personally and as such, I am deeply thankful to all those, who have facilitated this project. I am deeply grateful to Prof. Matthew O. Jackson who supported my application to become a visiting research student at Stanford and who supervised me during this period. It was an honour for me to be able to receive his feedback and I truly admire him for his ability to provide individual students with so precise and helpful feedback. The feedback from Prof. Jackson and the insights I gained during my time in Stanford provided the basis for the fourth chapter of my thesis. Furthermore, I had various opportunities to present my research at Stanford and obtained highly valuable feedback from this.

For my research visit, I held two scholarships, the Fulbright scholarship and a contribution from the Victor Halberstadt grant. I am thus very thankful to the Fulbright commission and to the Amsterdam University fund for financially supporting me during this period. I am further thankful to Michel Vellekoop for allowing me to use my Ph.D. travel budget on this project and to Frank Kleibergen for arranging the adjustment of my contract during this period.

I am thankful to my co-students both at the Tinbergen Institute (TI) and at the University of Amsterdam, who always provided me with the opportunity to engage in enriching discussions, but also with support and advice. It has been a pleasure to be surrounded with such a group of passionate and talented co-students.

It is unquestionable that in particular the education I received at TI was incommensurable for me to be able to conduct this research. I certainly think that the M.Phil. in econometrics program at TI indeed is an excellent course for aspiring economists in general and econometricians in particular. I am also thankful to the German Academic Exchange Service for having funded my studies at TI.

I am thankful to all members of the UvA econometrics group and the Center for Non-linear Dynamics in Economics and Finance for the great feedback and all the help I received for my research, but also teaching.

I would like to further express my gratitude to the Lisa-Surfsara team, who provided me not only with the opportunity to run my code on the large computer cluster, but also with tremendously helpful technical assistance. I was also able to attend several of the Surfsara training courses, from which I benefited enormously.

I am further grateful to the researchers from MIT and Stanford for making their data publicly available, so that I could use it for this project.

Finally, I am very thankful to my friends and my family who supported me during my ups and downs all the way throughout this project. Being an academic researcher is



fundamentally different to other professions and for me (who had previously worked as a consultant), this transition was not always an easy one. As such, the mental and emotional support that I received from my family was all the more important to me. Being a Ph.D. student at the UvA provided me with the space and the freedom to pursue my research interests, acquire skills, fall back, step forward and finally grow into a researcher and I am deeply grateful that I have had this opportunity.



# Contents

<b>Acknowledgements</b>	<b>i</b>
<b>1 Introduction</b>	<b>1</b>
1.1 Introduction . . . . .	1
1.2 Literature . . . . .	2
1.3 The Model, the Data and Previous Estimation . . . . .	4
1.4 Thesis Outline . . . . .	5
1.4.1 The “Two-period Estimator” . . . . .	5
1.4.2 The “Trimming Estimator” . . . . .	5
1.4.3 The “Moment-based Estimators” . . . . .	6
1.5 Conclusion . . . . .	7
<b>2 The Two-period Estimator</b>	<b>9</b>
2.1 Introduction . . . . .	9
2.2 Model and Assumptions . . . . .	12
2.3 Maximum Likelihood Estimation . . . . .	15
2.3.1 Potentially Informed Individuals (PIIs) - the origin of the dimensionality problem . . . . .	15
2.3.2 Computational Aspects . . . . .	18
2.3.3 Identification of the maximum by grid search . . . . .	19
2.3.4 Confidence Sets from Likelihood Ratio (LR) Tests . . . . .	20
2.3.5 Shortcomings of the original estimation procedure . . . . .	21
2.4 Model and Hypothesis Overview . . . . .	23
2.5 Data . . . . .	27
2.6 Models with Homogeneous Adoption Rates . . . . .	31
2.6.1 Model 1: Homogeneous Adoption and Diffusion . . . . .	32
2.6.2 Model 2: Homogeneous Adoption, Differentiate Diffusion . . . . .	35
2.6.3 Hypothesis Testing . . . . .	40

2.7	Models with Endorsement Effect . . . . .	40
2.7.1	Model 3: Endorsed Adoption, Homogeneous Diffusion . . . . .	43
2.7.2	Model 4: Endorsed Adoption, Differentiated Diffusion . . . . .	45
2.7.3	Hypothesis Testing . . . . .	46
2.8	Models including Co-variates . . . . .	49
2.8.1	Model 5: Socio-economically determined Adoption, Homogeneous Diffusion . . . . .	50
2.8.2	Model 6: Socio-economically determined Adoption, Differenti- ated Diffusion . . . . .	53
2.8.3	Hypothesis Testing . . . . .	55
2.9	Limitations . . . . .	57
2.10	Conclusion . . . . .	58
2.11	Appendix . . . . .	59
2.11.1	The Banerjee et al. (2013) Algorithm for Two Time Periods . . . . .	59
2.11.2	Appendix 2: Densities and Similarity Indices (Jacquard) . . . . .	62
2.11.3	Appendix 4: Parameter Variance in the Homogeneous Adoption and Diffusion Model . . . . .	63
<b>3</b>	<b>The Trimming Estimator</b>	<b>65</b>
3.1	Introduction . . . . .	65
3.2	The Model . . . . .	67
3.3	Establishing the (approximate) Log-likelihood function . . . . .	69
3.4	Monte Carlo Set-up . . . . .	75
3.5	Monte Carlo Results . . . . .	77
3.6	Real Data Application . . . . .	86
3.7	Conclusion . . . . .	90
3.8	Appendix . . . . .	90
3.8.1	Details on Establishing the (Approximate) Log-likelihood Function	90
3.8.2	Performance of the Algorithm . . . . .	95
3.8.3	Erroneous Choices . . . . .	97
3.8.4	The Error Function . . . . .	101
<b>4</b>	<b>The Moment-based Estimator</b>	<b>105</b>
4.1	Introduction . . . . .	105
4.2	The Model . . . . .	107
4.3	Unconditional Individual-Specific Moments and Moment Conditions . . . . .	110
4.3.1	Individual-specific Mean-Conditions . . . . .	110

4.3.2	Information Reception Probabilities . . . . .	115
4.3.3	Within-Village Correlation . . . . .	117
4.3.4	Parameter Identification from Individual Moment Conditions . .	121
4.4	Non-aggregated Estimator . . . . .	122
4.4.1	The Objective Function . . . . .	122
4.4.2	Identification . . . . .	125
4.4.3	Consistency . . . . .	125
4.4.4	Asymptotic Variance . . . . .	126
4.5	Two-moment GMM Estimator . . . . .	130
4.5.1	The Objective Function . . . . .	130
4.5.2	The limiting Function . . . . .	131
4.5.3	Identification . . . . .	132
4.5.4	Consistency . . . . .	133
4.5.5	Asymptotic Variance . . . . .	134
4.6	Comparison . . . . .	135
4.6.1	Small Sample Properties . . . . .	135
4.6.2	Consistency requirements . . . . .	137
4.6.3	Variance estimation and testing . . . . .	139
4.7	Monte Carlo Study . . . . .	139
4.8	Application . . . . .	144
4.9	Conclusion . . . . .	144
4.10	Appendix - Proofs of Theorems 1 and 2 . . . . .	145
4.10.1	Proof of Theorem 1 . . . . .	145
4.10.2	Proof of Theorem 2 . . . . .	146
4.10.3	First Order Conditions (Non-aggregated Estimator) . . . . .	147
4.10.4	Convexity of the Objective Function (Non-aggregated Estimator)	149
<b>5</b>	<b>Summary</b>	<b>153</b>
	<b>Bibliography</b>	<b>157</b>
	<b>Samenvatting</b>	<b>161</b>