nekst>>

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Special

Red Cross on Lifesaving Modelling

>> Triangle
Humanitarian Logistics Optimization

>> Special
Epidemics, Vaccines and Mathematics

>> Report
INFORMS Student Team Competition

On May 10-12, the Batavierenrace took place in Enschede and Nijmegen. 8500 students from all over the Netherlands (and Germany) participated, among whom also a team of econometricians!

Summer Vibes

Just like you, I will probably carry this year's fourth edition of Nekst with me. Whether you are exploring the streets of a bizarrely hot central European city, enjoying the nightlife at a boulevard in the Far East or busy "eenzaam de Polly uitspelen" during the upcoming months without lectures or deadlines: I hope you have a great time!

And when all intensity of these summer days gets the most of you, Nekst is there for you! To already get you in the mood for traveling, two Econometricians who just came back from their exchange, have written about their adventures in an Exchange Report. This Nekst, though, is not just about traveling: we are pleased to present you some pieces about how econometrics / mathematics can be used to improve society. We reached out to the Red Cross to get to know more about how they use mathematical modelling to help save lives of people in need. Moreover, our editorial staff has prepared two specials for you. Jeffrey and Guus dove into a case where data science is used in medicine and Stefan guides us through a model in the context of epidemics and vaccination.

It has been an incredible pleasure to provide you with suitable reading material between all the numbers and equations you have encountered the past academic year.

Yours cordially,

Dominique Bavelaar
Editor-in-Chief

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ASSET Econometrics

Dear Members,

Sadly the year is coming to an end and with that, this will be my very last "Dear Members" as chairman of this lovely association. With deep respect, love and inexhaustible enthusiasm, I look back to the wonderful year, but above all to the final months of this year in which we will do our utmost to bring the icing on the cake to our wonderful board year.

But talking about that, we forget about the achievements that have already been made. Because before you can put the icing on the cake your first have to make the cake, which is the most time consuming part of the entire process. Most noteworthy is, of course, the lustrum that we celebrated together. In one very full week, we managed to kick off the lustrum, meet companies, party like never before, recover from the resulting hangover, scout the woods and finally conclude all of this with the lovely gala. I am certain that I speak for all our members when I say that it was a wonderful week and would like to take a very last moment to thank the lustrum committee for the tremendous efforts during this year. With the closure of the lustrum week, the year is rapidly coming to an end. This will mean that with great regret it is time to say goodbye to our board year and soon we will resign as the board of Asset | Econometrics.

When the time comes to resign as the board of this magnificent association we will not leave it unguided. We have found five incredibly capable successors to lead the association forward. I will no longer keep you guessing for the new candidate board. For the academic year 2019-2020, the candidate board will consist of Denise Jacobs (Chairman), Marieke Derks (Secretary), Bastiaan Schutte (Treasurer), Ricardo van Belzen (External affairs), Britte Kragten (Internal affairs). You will have plenty of moments to get to know them in the upcoming months. As soon as you get to know them better you will be convinced why I am so confident about their capabilities.

With an ever growing association, they will certainly use their talents to do the very best for our members. One might think the year will become easy now that the lustrum is behind us, but do not underestimate their challenges: they will have to work on the new Hackathon Tilburg that will already be held on October 1. To make sure they will not get bored they can also put their minds to the brand new banking day.

By now, I have reached my very last words for the "Dear Members" and I would like to use these for you. I have told it before, but I cannot stress it enough. The strength of the association comes from its members. Your efforts have brought us where we are now. Thanks to your selfless commitment and never-ending enthusiasm the association has fared well and it makes me confident that it will fare even better in the upcoming years. Before ending this I want to thank some very special members, namely my fellow board members. It would not have been the same without you Wenxin, Jelle, Joris and Nina. You have brought us all fun and joy every day.

It was a wonderful year with all of you and I hope to see you all again next year!

On behalf of the board,

Quirien Raat
Chairman Asset | Econometrics 2018-2019

Experiencing Bilbao

Willeke Nieuwenhuizen

Bachelor EOR

Age: 21

I spend my Fall semester of 2018 in the beautiful city of Bilbao, located on the northwestern coast of Spain. Bilbao is the biggest city in the Basque Country, which is a part of Spain but has its very own culture and language.

But wait, I thought Econometricians could only do their exchange in places like Singapore?
Well, if you actually want to earn credits for EOR courses, your options are unfortunately very limited. There are no universities in Spain that offer Econometric courses. However, I was able to take both of my philosophy courses and my free elective abroad. Which means I gained a total of 18 ECTS, which is not so bad if you look at the average points scored per student in a semester at Tilburg University. But do take in mind that an exchange is likely to cost you an extra half year of your Bachelor.

Why did you choose Bilbao?
I think I must have answered this question a hundred times by now. Why would you go to Bilbao? Maybe you have never heard of this city; to be honest I do not think I had either before I started planning my exchange. Back in high school, I had already decided that I wanted to do my exchange in Spain. I started learning Spanish then and I was very excited to improve my Spanish skills. I thought it would be very cool to become fluent in a language other than English or Dutch. With my choice nailed down to Spain my options were basically Barcelona, Madrid or Bilbao. Barcelona only offered courses in Spanish or Catalan and this seemed to me as a dive a little too deep at the time. I applied for both Madrid and Bilbao but in the end I am very happy that it turned out to be Bilbao, because I think it is much more suited for an exchange semester.

Why is Bilbao such a nice city?
Firstly, it is neither too big nor too small. If you live near the city centre, most things can be reached with a twenty minutes walk. For example, to go to university I had to cross the city center, which took me 25 minutes by foot. However, it is big enough so there is always something going on. The old center, Casco Viejo, is always crowded with people enjoying drinks and pintxos on the streets. A 'pintxo' is a traditional Basque bite, a small dish comparable with a tapa like they have in the South of Spain. Bilbao has tons of small restaurants and cafes where you can get coffee, beer and pintxos for very good prices. Another good thing about the city is that it is located near the seaside. The metro takes you there in less than 40 minutes. There you will find beautiful sand beaches and the waves are perfect for surfing. Moreover, Bilbao is surrounded by mountains, ideal for taking beautiful hikes. Bilbao has nature, sea, good food, good ambiance. What more could you wish for?

Where did you travel?
I took my exchange semester as an opportunity to make as many trips as possible, and I think I succeeded in that pretty well. I went on a few organized trips with 'Happy Erasmus Bilbao' a local exchange student association. This is always a very nice opportunity to meet new people and a usually financially attractive option. My first trip was a weekend to Salamanca and Segovia. Two very nice Spanish cities, and a very cool party with other exchange students from Salamanca and Tequila shots for 50 cents. My second and probably most spontaneous trips was a weekend in Mallorca. Book some cheap flight tickets and a hostel a week before and you are ready to go. A week later, I visited my cousin in Barcelona and her family. Later in November, I made a very nice trip to Andalucía, a region in the south of Spain. Together with four friends I had made during my Erasmus semester, we decided to make a road trip in the South of Spain. But taking in mind that crossing entire Spain by car would take more than 12 hours, we decided to fly to Sevilla and rent a car there. We visited the beautiful cities of Sevilla, Cordoba, Grenada and Malaga and flew back from the last one. I also made a trip with my friend and fellow Econometrician Fleur, who did her exchange in Lisbon at the same time. We decided to meet up in the middle and explore Madrid together. And at the end of my exchange period I flew to Lisbon and we returned to the Netherlands together just in time for Christmas (and in time to take the Statistics exam, hooray).

Did you learn Spanish?
Si aprendí mucho, pero no tanto como quise. (Yes, I learned a lot, but not as much as I wanted.) I spoke a lot of Spanish in my language courses, in shops and restaurants and with my Spanish classmates. The problem, however, is that most Erasmus students who come to Spain do not speak a lot of Spanish and then English becomes a much more natural alternative. It turned out to be quite difficult to become good friends with local students. They were very nice during classes and I worked together with them on group projects. I joined them for coffee and pintxos at the café across the street during university breaks, but outside school they mostly had their own friends. Not very surprising of course, most students in Tilburg do not hang out with Erasmus students either. After all, they will leave after only a few months. Something that did really surprise me was the lack of skill in the English language of Spanish people. I always thought French people were really bad, but as it turns out, Spanish people are worse. When my parents came to visit me and we went to a not too touristic restaurant, the waiter would only talk to me in Spanish so I could translate everything to my parents. And even my classmates, who took more than half their courses in English, were not comfortable with speaking English. While doing group assignments, they would discuss their ideas in Spanish (which I could understand most of the time) and then I would explain mine in English, which they would understand. And when they had to write a report in English, they just wrote the entire thing in Spanish and then threw it into Google translate… Luckily for them, that worked a little bit better than when you translate from Dutch to English.

Would I recommend it?
Even though an exchange is an amazing experience, I am not going to pretend that there are no downsides. I met a lot of interesting people and learned about their cultures, I traveled, I learned Spanish and I went to a lot of great parties. However, there were also quite a few times that I was quite bored. The schoolwork was not that demanding and there were almost no extracurricular activities like participating in committees and such. Moreover, you do not have any family to visit nearby and a lot of activities you are used to doing at home that take up a significant amount of your time probably without you noticing, suddenly fall away. On one hand, this made my life very relaxed. On the other hand, I am the kind of person that likes to be busy and challenged, and I am glad that my life here in the Netherlands is a little more chaotic. So, would I recommend going on exchange? Definitely yes! Would I do another semester of IBA/Economics like courses? Probably not.

Exchange Higher School of Economics

Joost Broeders

Bachelor EOR

Age: 21

On August 20 last summer, it was finally time to go on my exchange. After a lot of planning and e-mailing, everything was scheduled and I was ready to go to Moscow. Many people always ask why I went to Moscow in the Russian Federation, but the answer is simple: I wanted an exchange that was special and have an experience I would never forget. My exchange in Moscow definitely lived up to that standard and I look back with great satisfaction.

Once I landed in Moscow, I immediately realized how different Russia was. Everything around you just feels and looks different. Arriving in Moscow is not the same as in Europe, even though flying there takes as long as flying to Spain. Everything was so overwhelming and different, but I enjoyed it from the very first second. Luckily, the university in Moscow, Higher School of Economics (HSE), assigned a Russian student to me, who would help me get from the airport to my dormitory. To put in perspective how different Moscow and Russia is, I paid a stunning € 20 a month for my dormitory room in the middle of Moscow. Once I came to the dorm I was immediately welcomed with open arms. After having registered and thanking the Russian people, who helped me, by letting them taste some classic Dutch stroopwafels: I was finally settled. Luckily, the dorm I was assigned to was just for other exchange students so making friends was easy. After the first day I became good friends with my neighbors on one side and even till this day I talk to them a lot. We even went on a trip around Europe together after our exchange so you can definitely say exchange was a lifelong experience.

After everyone arrived, the introduction program started. Like with any introduction, the first day activity was a formal introduction, which took way too long. However, after the introduction, we had a city tour around Moscow and here you saw the beauty of the city I heard about. Moscow is a stunning city and I would recommend everyone going there. It has immense classical buildings, and of course the very famous red square with the Kremlin and Sint-Basil's Cathedral. Moscow has a lot to offer and the city tour unfortunately did not do enough justice for that. Luckily, though, in the months following I got the opportunity the explore it and appreciate all the beauty the city has to offer. As per tradition every day of the introduction (and most of the days after that) ended with going to a bar. We managed to get a great group of people from all around the world and talked and enjoyed some beers.

After some relaxing days and some more formalities and bar visits, it was the time for the icing on the cake: the pub crawl. The pub crawl organized by ESN Moscow was an all-around splendid experience. The most famous bars with the best techno were shown to us with free shots at every bar. It is needless to say that at the end of the evening in the final bar where everyone met, everyone was going crazy and enjoying everything. Up until this day I still talk with friends of my exchange about this evening and all the crazy memories we have.

After introduction, it was time to study some say. I took it easy and decided to take less courses so I could fully enjoy my exchange semester by traveling around Russia and discovering Moscow to the fullest extent. Looking back, this is the best choice I made.

Almost every night, me and my friends went to famous big bars or clubs and enjoyed the cheap, but very good, vodka Russia had to offer. Currently, around 12 million people live in Moscow so finding a bar with people was not too difficult.

At daytime, we often walked around the city and enjoyed one of the millions of activities one can do in Moscow. Even though I went to Moscow for half a year, I did not even have time to do it all and I would certainly go back for more.

Besides Moscow, I visited many other cities. ESN organized trips to cities like Sint -Petersburg, Kazan, and Sergiyev Posad and me and my friends went by ourselves to Sochi.

Sint-Petersburg is a great and beautiful city and we had an amazing time there. The city heavily influenced by the Netherlands since one of the most famous and influential Russian, Peter the Great, fell in love with Russia and introduced many concepts of the Netherlands in Russia. One might say that for that reason Sint-Petersburg looks a lot like Amsterdam and I have to say you can clearly see the resemblance. At the end of the first day we had the very famous pub crawl. Of course, it was not as good as the one in Moscow but the time there was amazing. From singing Dutch songs in a karaoke bar with a Japanese friend of mine, to my British friend and I getting lost on our way back. The night was straight up amazing. The next night we had something special, the organizers from ESN know a special bar called Commode. This was not a special bar, but a hidden bar. Basically, it was just an apartment and if you knew where to look you might get in. Luckily for us, we could and it was simply amazing. The next day we went to the all famous Hermitage in Sint-Petersburg and after being frozen by a city tour we ended the week going back by our night train.

Shortly after that, ESN organized a trip to Kazan, the Muslim capital of Russia, and I decided to go there with friends. After a 14-hour train journey, which was hell, we arrived. Even though we were still in Russia, Kazan and Moscow are different like day and night. Two completely different cities and places, all in the same country. After having seen the beautiful city and having great evenings also this had, unfortunately, to come to an end.

Besides all other trip which were amazing, and I would highly recommend, my and my friends decided to do something special. In Russia the most common religion is Orthodox Christianity and for that reason they do not celebrate Christmas like we do. In order to have this ourselves we decided to rent a villa in the outskirts of Moscow and spent Christmas here. The result of this was an amazing Christmas with great friends and an amazing time. The location was amazing in the woods near a lake. Exploring it was a bit less fun, though, with a temperature of -20 degrees Celsius.

After all, it was almost time to go back home but not without New Year's Eve in Moscow, with Putin's famous speech on the Red Square. New years eve for Russians is what Christmas is for us, so everywhere there were special celebrations and beautiful firework. This was an amazing evening to end to exchange.

Looking back my exchange to Moscow was the most amazing time and I would recommend anyone to go on exchange and to visit Moscow at least once in their life. I learned that a lot of stereotypes I had about Russia are not true at all and how amazing the people are and how beautiful the country is.

Humanitarian Logistics Optimization

Humanitarian logistics is often described as the process of planning, implementing, and controlling the flow and storage of goods/information, intended to reduce the suffering of vulnerable people, from the point of producing to the point of consumption [2]. In this article we introduce two challenges that occur in humanitarian logistics. The first problem belongs to the class of preparations in order to respond to disasters. The second problem appears in the (immediate) response phase after a disaster hit a region.

written by **Valentijn Stienen**

Introduction

As you can imagine, the field of humanitarian logistics has a very broad scope. Therefore, the following four categories within humanitarian logistics are often distinguished [3]:

- The **mitigation** phase refers to the precautions that are taken to mitigate specific disasters. E.g., building *reliable* infrastructure.
- The **preparation** phase refers to the operations that occur during the period before a disaster strikes. E.g., storing additional relief items in disaster prone areas.
- The **response** phase refers to the actions taken within the first few days after a disaster occurred. E.g. providing first aid (food, supplies, medicine) to people that are stuck in a flooded area.
- The **development** phase of a disaster consists of the operations done in the months/years after the disaster occurred. E.g. long-term recovery operations.

In this article, we treat two different optimization problems related to these phases. First, a problem is discussed which belongs to the *preparation phase*. We determine optimal locations for pre-positioning relief items. The second problem is related to the *response phase*. Here, we try to optimize decisions regarding the routing of relief items to affected people. We incorporate the high uncertainty about the (road) conditions in the disaster area.

Optimal pre-positioning locations

When disaster strikes an area, international assistance (e.g., international relief organizations) is often requested to help responding and recovering from the disaster. This response can be characterized by the dispatch of relief items (e.g., tents, tarpaulins, food or hygiene kits) to the affected regions. To enhance response capabilities, humanitarian organizations often make use of pre-positioning their inventory. This may significantly reduce the time it takes to deliver emergency items to the affected people. However, it is often not easy to store goods anywhere in the world.

This is where Humanitarian Logistics Service Providers (HLSP) come into play. A HLSP offers services to humanitarian organizations that improve the supply chain of these organizations. For instance, an HLSP may offer storage locations in specific regions of the world. One of the largest HLSPs is the United Nations Humanitarian Response Depot (UNHRD). The UNHRD offers free storage space to humanitarian organizations (for free) in multiple locations across the globe. In this way, organizations can implement these locations in their pre-positioning network. Besides that, the UNHRD offers to ship the stored relief items to the affected regions on behalf of the humanitarian organizations. This may result in lower costs due to bulk shipments/flights. The first question we now try to answer is how to distribute three HLSP depots across the world in an *optimal* way.

We determine the optimal distribution of depots based upon historical data from EM-DAT [1]. We try to find depots, which are located in an optimal way for the historical disasters. In particular, we assume that the depots store relief items intended for countries with a Human Development Index (HDI) smaller than 0.8.

This problem can be formulated as a basic Facility Location Problem (FLP). Let $\mathcal{H}$ be the set of possible depot locations and let $\mathcal{D}$ be the set of disasters that will be assigned to depots. We denote the cost of supplying disaster d from possible hub locations h by c_{hd}. Furthermore, let y_h be a binary variable that indicates whether depot h is opened ($y_h = 1$). Finally, let x_{hd} be a non-negative variable indicating whether disaster d is supplied by (open) depot h. Then the FLP can be described as in Model 1.

The first constraint ensures that disasters can only be supplied by *open* depots. The second constraint makes sure that each disaster is supplied by a depot and the third constraint bounds the total number of open depots to three. There are some additional pre-processing steps required to solve this model. To determine the set of possible depot locations $\mathcal{H}$, we select locations that both contain a large harbor and airport. Both

$$
\begin{array}{lll}
\text{minimize} & \sum_{h\in\mathcal{H}}\sum_{d\in\mathcal{D}} c_{hd}x_{hd}, & \\
\text{s.t.} & x_{hd} \le y_h, & \forall h \in \mathcal{H},\ d \in \mathcal{D} \\
& \sum_{h\in\mathcal{H}} x_{hd} = 1, & \forall d \in \mathcal{D} \\
& \sum_{h\in\mathcal{H}} y_h \le 3, & \\
& x_{hd} \ge 0, & \forall h \in \mathcal{H},\ d \in \mathcal{D} \\
& x_{hd} \in \mathbb{R},\ y_h \in \{0,1\}, & \forall h \in \mathcal{H},\ d \in \mathcal{D}
\end{array}
$$

Model 1: FLP model

restrictions ensure that relief items get dispatched as easy as possible. The set of disasters $\mathcal{D}$ contains all disasters reported in the EM-DAT between 2017 and April 2019, which affected at least 100 people. Finally, the cost of assigning a disaster to a depot is computed as follows. We assume that part of the delivery to a disaster is done via sea and part is done with aircraft (the immediate response). Figure 1 illustrates the costs involved,

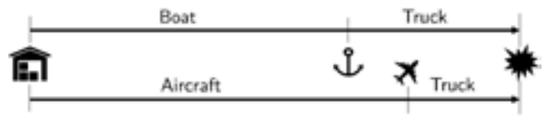

Figure 1: Cost of supplying a disaster from a depot

This means that we first map each disaster to its nearest harbor and airport. Subsequently, we can determine the total transportation cost by summing up the total truck/boat/aircraft costs.

Solving this model gives us the distribution of depots that generates the least amount of transportation costs. The total minimized cost is $1.53B. However, in humanitarian context, costs do not solely determine the quality of the solution. Another important factor for pre-positioning depots is the *maximum response time*. This is a quantity that is supposed to be minimal as well. Let t_{hd} be the response time when disaster d is assigned to depot h. Then, the second objective of the FLP is minimizing:

$$\max_d \left\{ \sum_{h\in\mathcal{H}} t_{hd}x_{hd} \right\}$$

Now, our focus becomes finding the Pareto front of the FLP with the two objectives. First, we solve the FLP only minimizing the maximum response time. The solution is a distribution of depots from which humanitarian organizations can respond within 28 hours. Next, we minimize the transportation cost while ensuring that the maximum response time equals 28. The result is a cost of $1.98B. Computing the minimal cost for an increasing response time (in hours) results in the Pareto front shown in Figure 2.

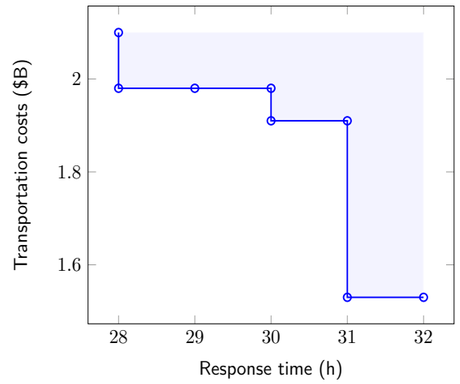

Figure 2: Pareto front for the pre-positioning problem.

From Figure 2, we can see that there exist 3 *strongly* Pareto optimal solutions. For clarity, we visualized these three solutions in Figure 3. The blue dots represent the considered disaster locations. Disasters with a high number of affected people are displayed with a larger dot.

As we expect, allowing for a higher maximum response time results in optimal depot locations which are moved to the regions where disasters affected the largest amount of people.

Routing relief items

Next, we discuss the problem of routing relief items in a disaster area in which there is uncertainty in the road conditions. We will work through a simple example to show how decisions can be optimized. Consider the situation in Figure 4.

We want to deliver relief items from the harbor (H) to the disaster area (D). We can deliver via two additional cities, A and B. The edge labels represent the distances between nodes. The jagged edge between B and D means that we are currently not sure whether this road is destroyed or not. We assume that we can use this road with probability 0.5. Finally, we assume that we are allowed to decide the direction of the truck each time it visits a node.

When ignoring the probabilities, the shortest path solution ($H \to B \to D$) is optimal (length 9). To incorporate the probabilities, we seek a strategy that minimizes the *expected* length of the route to the disaster site. We model the situation as a Markov Decision Process (MDP) as is done in [4].

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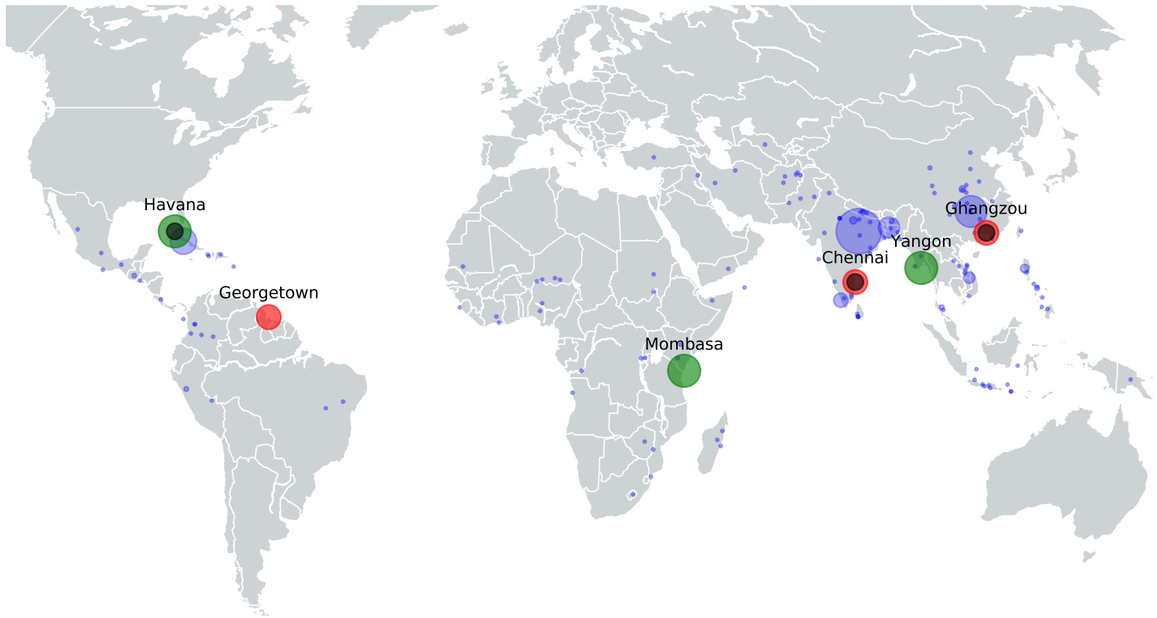

Figure 3: Distribution of the optimal depot locations for each strongly Pareto optimal solution. The black dots correspond to the solution with a maximum response time of 31h, the red dots correspond to a maximum response time of 30h and the green dots correspond to the solution with a maximum response time of 28h.

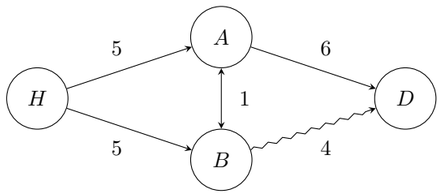

Figure 4: Example situation

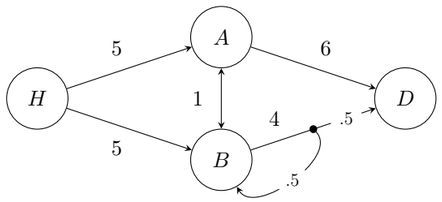

Figure 5: Example situation including probabilities

Figure 5 is a new representation of the example in which the jagged edge ($B \to D$) is replaced with an edge containing a dot in the middle. This edge can be interpreted as follows. If we choose to traverse edge $B \to D$, we always cover a distance of 4. Then, we either end up in D or in B (when the road turns out to be destroyed), both occurring with 50% probability.

Let $\mathcal{S} = \{H,\ A,\ B,\ D\}$ be the state space of the MDP. Furthermore, in each state s we have a set of actions $\mathcal{A}_s$. For instance, $\mathcal{A}_H = \{Goto\ A,\ Goto\ B\}$. Next, we assign a value to each state s that represents the expected minimal distance from state s to the disaster site D. I.e., $x_D = 0$ and the values for the remaining states can be written as follows:

$$x_s = \min_{a \in \mathcal{A}_s} \left\{ w(s,a) + \sum_{s' \in \mathcal{S} \setminus \{D\}} p(s,a,s')\ x_{s'} \right\}, \quad (1)$$

where $w(s,a)$ denotes the distance traveled when action a is chosen while in state s. $p(s,a,s')$ is the probability of ending up in state s' starting in state s when choosing action a. If the truck is currently in state s, then the optimal action is the a that attains the minimum in (1). To find these values we can solve the following linear program:

$$\begin{aligned} \max \quad & \sum_{s \in \mathcal{S} \setminus \{D\}} x_s, \\ \text{s.t.} \quad & x_s \le w(s,a) + \sum_{s' \in \mathcal{S} \setminus \{D\}} p(s,a,s')\ x_{s'}, \\ & \qquad \forall s \in \mathcal{S},\ a \in \mathcal{A}_s. \end{aligned}$$

Note that the values of states can change over time when information about road conditions becomes available. This means that when new information becomes available, the values need to be updated.

Next, we discuss the numerical results for the example introduced before. When the truck starts in the harbor, the values of the states (minimal expected distances to D) are $v_H = 11$, $v_A = 6$ and $v_B = 8$. For instance, if we start in A, we need to traverse at least an expected distance of 6 to reach D. To find the current optimal decision, we determine for each state the action that results in the minimum value, i.e.,

- *Goto A*. First, we drive a distance of 5 ($H \to A$). Then, we expect to drive $x_A = 6$. Total: 11.
- *Goto B*. First, we drive a distance of 5 ($H \to B$). Then, we expect to drive $x_B = 8$. Total: 13.

Minimizing the total expected length results in choosing to go from H to A. Once arrived in A another decision has to be made. Suppose that now it has become known that the road between B and D is open. This means that we update the values of the states, $v_H = 9$, $v_A = 5$ and $v_B = 4$. Again, we compare,

- *Goto D*. First, we drive a distance of 6 ($A \to D$). Then we arrive at D. Total: 6.
- *Goto B*. First, we drive a distance of 1 ($A \to B$). Then, we expect to drive $x_B = 4$. Total: 5.

Hence, we choose to go to B. Similarly, our last choice will be to go from B to D. In short, the path we traversed is $H \to A \to B \to D$. This path is not the shortest path, but it took into account that the edge $B \to D$ might have been destroyed.

Conclusion

A challenging part of doing research in the field of humanitarian optimization is to provide solutions to problems that can actually be used by humanitarian organizations. On the one hand, the *problems* which are addressed need to be aligned with the problems faced by the humanitarian organizations. On the other hand, the *solutions* that are found need to be accessible and implementable by humanitarian organizations.

The first project described is done is close cooperation with the UNHRD. In this study we include additional factors specific for UNHRD. For instance, we consider the political difficulties of establishing a depot in a country. Furthermore, we consider other scenarios such as optimally expanding their current network, by allowing one hub to be added to their current network. For the second study, we are developing more realistic models. For instance, using adjustable robust optimization, we try to include information about when road conditions are examined and reported.¨¡

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Valentijn Stienen
Ph.D. candidate

The "Fuifkar"

Juliette Tillie

Bachelor EOR

Age: 20

As a freshman there are loads of activities being hosted for you. On a quiet night on April 17, one of these activities took place. Namely: the "wagoncantus", or in Dutch: huifkarcantus. Not only the freshmen but also the second-year students were welcome to help build this party.

At 20.00 hours the group gathered in front of the Albert Heijn XL to enter the covered wagon filled with disco lights and four long benches. As soon as the tractor, which pulled the wagon, started to drive, the music volume was turned up and the first beers were downed.

While we were still sober enough for practicalities like this, Tjum and I decided to hand a beer to a biker while passing him. Our good deed did not give us good karma, as later in the evening we had to do a strafadje; downing your beer in a particular and normally not-so-comfortable way, as a punishment. The group decided that we had to drink out of our sweaty socks. To make matters worse I had followed a Zumba lesson just moments before the Cantus started... It is probably obvious that this was not my favorite part of the evening. This did not spoil the fun, though, and it certainly did not make me quiet.. resulting in me having to do a second strafadje. This time I was turned upside down and beer was poured in my mouth, also known as adje bat. Maybe wearing a white shirt was not my best decision that day…

We were not the only ones to be punished. Some adje promo's were also handed out. This means that one person has to take a big zip of beer and spit this in the other person's mouth, who then has to swallow this. This to the greatest entertainment of those not involved.

The tractor drove on and we left Tilburg behind us to go for the open fields. I think we spent more than 90 minutes driving around in the middle of nowhere. Luckily, we passed by the university where there was an opportunity for a sanitary stop.
Back on the wagon there was one song that was particularly popular. I heard this song for the first time ever during AMW this past weekend but I think I have heard it for at least 300 times by now. I am of course talking about "weeeee like to drink with ...".

One by one, everyone had to down their beer in 8 seconds, otherwise they would be called out. How lovely is this game?

The combination of all the punishment adjes, the 'we like to drink'-song and off course the cantus itself had us fairly drunk.

Thinking back of that night, I feel welcomed. Now that the year has progressed and we have made multiple memories together, I feel involved and included in the group of first year students. Having an activity for first and second years students in April was a great initiative and I am very glad to have participated. Cheers to many more nights like these!

Offspring

In my personal as well as academic life, children as well as grandchildren contribute to my well-being.

In personal life I have three daughters, one of whom even made it to the Board of Asset Econometrics and will finalize her MSc program within soon (she promised). By now, all three daughters also have a boyfriend, one of them also an econometrician. This suggest that partner choice is not a fully random draw from all available Dutch boys, but that is well known. Several colleagues of mine in the department of econometrics are married to a fellow econometrician.

In my phase of life (some five years before retirement) grandchildren take at least as much time as children do. By now I also have three grandchildren. Dolf Talman once drew my attention to the key difference here in terminology between Dutch and English. Grandchildren are referred to as Smallchildren in Dutch. I have changed the word I use in Dutch and now refer to the five year old as my "grootkind". She really loves it. The youngest grandchild currently has to be in hospital with his mom. Consequently I read papers, prepare lectures and participate in the national pension debate from a camping site close to that hospital in Apeldoorn. Thanks to all the IT that we nowadays have, all this is easily feasible. But occasionally I have to leave the camping site early in the morning dressed up as the Finance professor that I also am. Fortunately, at that time in the morning all other camping guests are still asleep.

Children and grandchildren are equally important in academic life. It is great fun to meet again with students that took your class or that you supervised when writing their Msc thesis and now work in all kinds of positions. The link with PhD students is even closer and successful careers for PhD students that you supervised contribute to your reputation. Quite a number of my former PhD students are well known full professors now, some five of them in Tilburg. The odd thing in academic life is that they are occasionally your child as well as your boss, e.g. as head of department. For example the current vice dean of research in Tilburg, Joost Driessen, is a former PhD student of mine. In academic life one can even breed new offspring with one of your children. While this is would be referred to as incestuous in personal life, one can train a new PhD student jointly with another supervisor that was once your PhD student. Bas Werker is an example here, once my student but later a joint supervisor on many successful projects. Marno Verbeek, now at Erasmus, who first year students could recall from his well known introductory econometrics textbook, is another example.

Nevertheless the danger of incestuous breeding of offspring is an issue in academic life as well. It is quite important to assure that PhD students are not just exposed to comments from their own supervisors but get feedback from a much broader research community, at their home university but ideally also at other universities. Feedback from other researchers, attendance of conferences, seminar presentations and research visits abroad are a key ingredient to produce healthy offspring. This is not automatically assured. As a member of the Tilburg committee for academic integrity I am involved in analyzing some of the academic scandals that damaged Tilburg's academic reputation in recent years. A common element is that PhD titles were awarded to candidates without appointments at Tilburg and without the proper feedback that a Graduate School should arrange. It is again as in personal life. Parents play an important role, but children need friends and feedback from others than just their parents.

Theo Nijman
is professor of Financial Econometrics in the EOR and Finance departments. Theo is Scientific Director of Netspar, a knowledge network with eight universities and many private partners from the pension industry. Besides his academic work, he is heavily involved in pension regulation and reform in the Netherlands.

Lifesaving Modelling

How the Red Cross uses mathematics to deal with catastrophes all over the world

written by **Dominique Bavelaar**

As soon as you turn on your television or Ziggo-Go app after dinner, it is reasonably likely that you end up seeing some footage from a war zone or a natural disaster somewhere on earth. Wherever these nasty events may happen: members from the Red Cross will be there - or are trying to get there- to save lives of people affected. Since in the process of providing aid, where time is costly, many choices have to be made, it may not sound too surprising that mathematics can be used to optimize this process.

Bart Rutten and I had the chance to meet Jannis Visser, who works full-time at the Red Cross. He started working there three years ago after a career as a Data Science consultant. At the time, the Red Cross just started *510*, an initiative to make more use of data within the organization. Jannis: "We have a team consisting of 15 people working full time on 510. Also, approximately just as many thesis interns help us with researching projects."

Dealing with typhoons

All projects within 510 are used in the context of humanitarian aid. An interesting project is about dealing with the impact of typhoons in East-Asia. Jannis: "Our job is mainly to make the work of our people at the location of the disaster easier. For example, the Philippines are hit regularly by typhoons. We made a tool which makes it possible for people on the ground to assess which particular parts of the country are most vulnerable to be struck by typhoons in the near future. And in case a flood wave already has occurred, our tool makes it visible which locations are most likely to be devastated. "

Given the data, the model behind the tool can determine the probability that a disaster takes place at a particular place and also assess how vulnerable the inhabitants are in case of a typhoon. "Collecting the data," Jannis remarks, " has to be done largely in a non-automated way. However, we can access impact data of typhoons that have occurred in the past. In the Philippines, this is documented reasonably well." Furthermore, data on how houses are built in (parts of) cities is very important to assess natural disaster vulnerability of a specific area. Jannis: "One can imagine that areas where a lot of houses have wooden walls suffer more damage in case of a flood than urban areas with buildings made of stone. Using machine learning techniques, we built a model which performs reasonably well for prediction." This model cannot, however, be easily implemented in other countries too. Jannis: "It is quite unique that impact data of previous disasters is documented as well as in the Philippines. In Zambia, for example, the only data at hand is whether or not there was a flood at a specific point in time. In such cases, we need to use different techniques."

A datatype used frequently in the forecasting settings the Red Cross faces, is geodata, with which we, as econometricians, are not too familiar. Jannis: "We use satellite pictures of pieces of land to learn about characteristics of a region. In case we see on such a picture that an area is flat, mountainous or densely vegetated, we can use this to improve our forecasts about the impact of a flood, for example. " This sounds quite tough, but according to Jannis, this is not really the case if you are familiar with other machine learning and data science techniques: "I would say, having an econometrics background, it is actually a quite fun skill to learn."

Forecast based financing

The model for typhoon related forecasting is finished, but not yet fully operationalized. Jannis: "We are currently working on an extension which tries to asses aid needed when the typhoon is not yet over. This model would then already indicate that, for example, a village in the north of the country will probably need food and within two days, even though the typhoon has not yet arrived there." In practice, this would mean that the International Federation of the Red Cross automatically releases funds because certain forecasted trigger levels have been exceeded. These can be used locally to mitigate the upcoming impact. "This is," Jannis remarks, "highly technical on one hand and highly political on the other. If, namely, funds have been provided because of model output, whereas in retrospect, it was not necessary, this has consequences. It is our job to make the model such, that this balance is rightly made."

This, so called, forecast based financing is currently implemented in different other countries for different disaster types. Jannis: "In Peru, we use a similar model for floods. For Zambia, Uganda and Kenia we are currently working on a model."

Alternative humanitarian aid

Another big project Jannis and his team are working on has to do with a recent development in the humanitarian sector. Jannis: "We want to head towards a situation in which we provide humanitarian aid not in terms of goods, but in terms of cash. This has a few motivations: first of all, many of areas in the world are hard to reach with huge amounts of blankets, foods or medicines in trucks or planes. Handing out cash would solve this issue. Moreover, people themselves know best what they need in a disastrous situation and such a system would stimulate local markets, though only in case these are sufficiently well functioning." This sounds maybe a bit risky in the sense that this requires a sufficient amount of sense of responsibility among individuals. However, according to academic literature, people act responsibly with the money they are provided with in such situations. Jannis: "We try to set up an end-to-end system where donors from all over the world can donate money, meant to mitigate a disaster, which makes the system transparent. " The goal is to assess vulnerability of individuals in areas where a humanitarian disaster is bound to happen, given data about the situation. According to this vulnerability profile, an amount of cash is allocated to an individual. Jannis: "There are still huge challenges ahead, though, before this can be implemented. Digital identity protection, fraud possibilities and privacy issues have to be addressed properly."

Thesis intern projects

Besides the big projects mentioned before, at 510 also several students perform research in the context of their master theses. The nature of these projects is quite diverse and concerns different types of disasters. Jannis: "Someone is developing a model to forecast food security in Ethiopia, based on geodata. Using the color of grass in combination with measured rainfall in the past, one can compose a dryness index, which helps to point out vulnerable areas." Currently, students are also forecasting the development of epidemics.

As you can read, mathematics and data science are used in an interesting and relevant way at thel Red Cross. We would like to thank Jannis for his time and insights in the interesting world in the intersection of humanitarian aid and data science. In case you want to learn more about 510 or the Red Cross in general, you may wish to visit *www.510.global*

From left to right:
Ties is 22 years old and has finished his Bachelor's degree in International Business Administration (IBA). He is the chairman of the board.
Pam is 22 years old and has finished her Bachelor's degree in IBA as well. She is the treasurer and operations manager of the board.
Rik is 22 years old and has finished his IBA Bachelor's degree as well. He is the external affairs officer of the board.
Barbara, calling herself the 'grandma' of the board, is 23 years old and has finished her IBA Bachelor's degree as well. She is the vice-chairman and the secretary of the board.
Linde is 22 years old and has finished her IBA Bachelor's degree. She is the public relations officer of the board.

The EBT: Our Exciting Board Time

written by **Marieke de Leeuw**

One could hardly have been unaware of the fact that from April 1 until April 18 this year, the Economic Business weeks Tilburg (EBT) took place again. If one has visited our campus in February, he has probably been handed out a flyer during that month and some of our readers may even have participated in the EBT. However, little might be known about the people who have organized this event; the EBT board 2019. On a Wednesday afternoon, Aurel and I sat down with the board and asked them some questions to get to know them better and about their experiences doing a board year.

Is it a coincidence that all of you have a background in studying IBA?
Linde: "Actually, it is the intention to have as much variety as possible within the board of EBT, so it is not very common that we all have finished the same degree."
Pam: It might be caused by the fact that there are just many IBA students and that Asset | International Business & Management counts many active members. In this way, these students are getting involved in the option for a board year somewhat easier.

Why did you choose to do a board year at EBT 2019?
Barbara: "I wanted to do a board year at EBT in particular because of the intent of this event. I think it is very important that students get the opportunity to get in contact with companies and I wanted to be part in the organization of that."
Rik: "I took part in the EBT a few times before and I was impressed by its magnitude and how cool this event is. Therefore, I wanted to organize it myself. On top of that, before starting my master's degree, I wanted to have a well spent gap year."
Pam: "During our active years at Asset | International Business & Management, we have all been part of several different committees, both formal and informal and some of us did an Asset-wide committee as well. I think joining the EBT board was the next big step all of us wanted to take."

Have you organized the whole EBT 2019 on your own or are there some committees beneath you?
Ties: "In principle, the five of us arrange everything, from a macro level up to a micro level. So, this boils down to on one hand, making sure that there are enough participating companies and on the other hand, counting the chairs in the rooms that were reserved for, e.g., a company presentation."
Rik: "However, we did get help from the Asset-wide business night committee in organizing the business night, which is the opening of the EBT. Moreover, during the promotion period and the EBT itself, we also got help from other Asset board members."

How does an average day at the office look like for an EBT board member?
Pam: "Well, actually it is not really possible to talk about an average day for us, since this depends on your function within the board and the time of the year.
The only sure thing was the board meeting at Monday mornings, where we updated each other about the progress made in the previous week. In this way, we could see what still needed to be done and make a task division for that."
Rik: "In June last year, we already started with the preparations. I spent the summer e-mailing and calling companies to make them participate in our event. Sometimes, when this provided added value, I went to visit a company to persuade them to take part in the EBT. From February on, we started to work towards the event itself, by promoting it."
Linde: "Unlike the board of an association, we are only working on one huge project that needs to be finished at the date it takes place. We do not have an association to run with several temporary side projects. If this would be the case, it would have been much easier to think about an average day at the office."
Barbara: "At least it included being present at our office all day, from 10.00 hours until 17.00 hours. Approaching the event, this is even longer. Now that the event is over, we are busy evaluating it and writing the transmission for the new board, which we already have chosen."

How are you trying to make sure that you attract people from different studies to your event?
Rik: "Obviously, the variety of students that are willing to take part in our event is depending on the companies that are present. Keeping this in mind, we try to invite companies from as many different industries as possible. We see it as a challenge to serve more and more different kinds of students. We see that relatively few Econometrics and Operations Research (EOR) students participate in our event, which may be the case because of the fact it is relatively hard to find companies that are completely focused on econometrics. We try to compensate this with the bigger companies that we invite, which will likely have room for EOR students."
Ties: "To make sure there is indeed a great variety in companies, we have a word with the boards of all different Asset departments during the acquisition period. They might have some useful ideas for companies to invite as well."

What did you learn during your board year?
Barbara: "Practically, I learned to use InDesign, a program that I used to make our promotion magazine. In addition to that, I came in touch with a feeling of great responsibility that one has when being part of a board, for example to appear at the office every day."
Linde: "Together with that feeling of responsibility I learned to take initiative more. When being part of a board, nothing will not happen if you do not arrange it. Over a thousand students and more than 80 companies are counting on you and that everything is going perfectly."
Rik: "In my function as the external affairs officer of the board, I improved my communication skills a lot. I have emailed and called with hundreds of companies and even visited a few of them."
Pam: "For me, things I have learned are merely for practical purposes, such as dealing with accounting programs and how to do tax declarations. Oh, and I learned to say 'no' a lot, when a fellow board member asked me again whether we had the budget to do certain things."
Ties: "Personally, I think I have improved in taking leadership of a group of people. In the beginning, I felt a little uncomfortable giving tasks to other people. By now, I have found a way to encourage people to do something without being too compelling."

What do you consider as the most fun part of your board year at EBT?
Everyone agrees that the Economic Business weeks Tilburg itself were the most fun part of their board years.
Linde: "For months, we have been working towards those three weeks and seeing the result of that is very satisfying."
Rik adds: "This feeling becomes even better with all the positive reactions about the event we have received."
Barbara: "Besides the success of the event itself, I found it very nice to have learned to work with InDesign, which is something that I normally would have never learned during my studies."

Is there anything unexpected that you faced when organizing this event?
Rik: "Before I started my board year, I was not aware of how things really work within the association and all its governing bodies in terms of cooperation. Sometimes, when decisions and agreements needed to be made, that process was slowed a bit due to the engagement of different parties, all having their own opinions."
Ties: "And, when inviting certain companies to our event, we had not thought of the fact that this could trigger a protest group to come and demonstrate during the lunch at one day. The corresponding company has been participating in our event for the last fifteen years, we simply did not take this into account. From another perspective, it does show involvement with our event regarding to the students at issue. We are having conversations with them to look how we can make the EBT more of a 'green' event."

Would you recommend doing a board year at EBT?
All board members agree that they would recommend doing a board year at EBT.
Pam: "Especially to Econometrics and Operations Research students! In this way, the event might attract more econometrics students as well as companies."
Rik: "Besides that, during a board year, you learn a lot. You need to deal with multiple parties, such as companies but also the university and you are organizing the biggest professional event of Tilburg University. This brings a lot of responsibility with it, in my opinion more than in the case of my exchange which I did during my Bachelor."
Ties: "As a board member of the EBT, you are somewhat in between student life and the professional world. I found that a very pleasant position."
Linde: Guys, do not forget to mention that it is also just very much fun!

All of you sound very positive, would you do an EBT board year again yourself then?
Everyone agrees that although they enjoyed their board year so much, they would never apply for a board year at EBT again.
Ties: "I am afraid that I would not be able to do it with the same (big) amount of enthusiasm. Therefore, no second board year for me. In fact, at least for next year I am not planning to join any board or committee at all. I am starting my Master's degree and I want to focus on that."
Barbara: "With the event just behind us and still being busy with the evaluations, I would like to do something different again. It takes a lot of energy. However, do have plans to join Asset | Marketing and to become active in a formal committee there. This is mostly to socialize a little rather than anything else, though."
Pam: "If we would be doing a board year for the second time, I think it would be less of a challenge to us. Basically, we have seen everything that comes with doing a board year at EBT already by now."
Rik: "I agree with Pam. However, if I ever would get the opportunity to have a job that includes doing comparable working activities, I would certainly take it. For next year, just like Ties I will focus on my Master's degree, which I will be starting in September."
Linde: "The same yields for me. I would be happy to do something similar, but not at the same place again. Regarding EBT, we have seen everything already and we found it amazing."

The Framingham Heart Study

A case study in the history of data science in medicine

written by **Jeffrey Buijk and Guus Vlaskamp**

Healthcare has always been an important subject for mankind. So it is no surprise that any and all developments in science find their way into the medical profession. As we all know, data science and machine learning are fields with great potential, in any application, and therefore we see more and more use of these techniques in medicine. However, contrary to popular belief, the rise of data science and statistical analysis in the field has been going on for quite a long time. On of the most notable examples of the long history of statistics in medicine is the Framingham Heart Study. This study started already in the late 1940s and has helped to get an insight in the causal of heart problems. What is the story of this study? What impact did it have? And to what degree are we breaking new grounds in the last decades?

The development of the study

In the begin of the 1930s the study of disease frequency of heart problems started, because of observed changes in causes of mortality. Several studies were implemented to unravel the cause of cardiovascular diseases, of which the Framingham Heart Study in 1948 is one. The Framingham Heart Study includes different cohorts, containing participants from three different generations. The first cohort, which is called the Original Cohort, included 5209 healthy residents between 30 and 60 years of age. In 1971, the second cohort was formed, which was called the Offspring Cohort. This cohort included all 5124 sons and daughters of the Original Cohort. More than 30 years later, in 2002, the final cohort was formed, which was called The Generation Three Cohort. In this cohort all 4095 participants were third generations of the Original Cohort and only participants that were 20 years or older were included. The aim of the study was to find risk factors of cardiovascular disease, which are independent and significant predictors of heart problems.

The Framingham Heart Study was focused on arteriosclerotic and hypertensive cardiovascular disease, since these are the most important of the cardiovascular diseases and the least was known about them. For the Framingham Heart Study, a group of persons was randomly selected in the age groups where arteriosclerotic and hypertensive cardiovascular disease were known to develop. Based on a clinical examination, from this group only the persons that did not have definite signs of these diseases were selected. These persons were observed over a period of years, until a significant number of the test group had started showing symptoms. The idea of the study is that once this has happened, the factors which influenced the development of these diseases would be researched.

Population

With this study set up, it was then important to define the population on which the study would be carried out. Since it would be difficult to investigate persons that live far from each other for a long period, a town of 25.000 to 50.000 inhabitants was chosen, from which approximately 6.000 persons would be included in the study. A disadvantage is that by choosing persons from the same town, geographical factors would not be included in the study. However, there was reasonable basis for the belief that within-community variance of a single area would be very much greater than between-community variance of different geographical areas for the distribution of arteriosclerosis and hypertension. After a consideration of possible areas the town of Framingham was selected. Framingham is a town located approximately 34 kilometers west from Boston and a reason why it was selected, is that the first study of tuberculosis was undertaken in this town, which began in 1917 and continued successfully for six years.

For the age group it was decided that only persons from 30 to 59 years old were investigated. This age group was chosen since younger people would have a small probability of developing arteriosclerotic and hypertensive cardiovascular disease in the upcoming 20 years, while in the older group there would be a too large proportion with pre-existing cardiovascular disease. The selected individuals were observed for 20 years and in case someone decided to move from Framingham, for this person a comparable examination would be set up elsewhere. When individuals from the test set died, an attempt was made to secure autopsy data and at the very least, complete description of the cause of death and data of cardiovascular diseases at the time of death were stored.

At the begin of the 1970s the second cohort of the Framingham Heart Study started. This cohort was called the Offspring Cohort, since it contained the children of the Original Cohort. Over 5000 persons have been identified to be allowed to participate in the study. The Framingham Offspring study had two main aims. Firstly, the study did want to determine whether there were changes in risk factors for the two different generations in generally. The second aim of the study was to examine the presence of familial and genetic effects in determining the levels of these risk factors. By allowing 22 years between the two studies, the offspring were examined at approximately the same age that their parents were at the start of the original heart study. The examination offered to the participants of the Offspring Cohort is similar to that taken by their parents.

In the first two cohorts of the Framingham Heart Study there was not much difference in ethnicity between the different individuals participating in the study. In order to be able to examine the influence of ethnicity on the probability of suffering from cardiovascular disease, the Framingham Heart Study decided to start the Omni Cohort Study in 1994, consisting of Hispanic, non-Hispanic black, Asian and Native-American residents from Framingham and 24 surrounding towns. The results of this cohort were compared with the results of the Offspring Cohort. To keep all variables other than ethnicity between the different cohorts as close as possible, only individuals older than 55 years old were used from the Omni Cohort. Approximately ten years later, the Framingham Heart Study have decided to start the Generation Three Cohort and the Omni Two Cohort, which contains the children and spouses of respectively the Offspring Cohort and the Omni Cohort.

As a result of the Framingham Heart Study it has been discovered that certain variables do have an effect on the probability of suffering from cardiovascular disease in the future. Based on these variables it is possible to approximate this probability based on a regression model, which is called the Framingham Risk Score.

The Framingham Risk Score

Based on the data of the Framingham Heart Study a score system could be designed, which estimates the 10-year cardiovascular risk of an individual. This Framingham Risk Score is based on a Multiple Logistic Regression Model and includes age, systolic blood pressure, cholesterol, high-density lipoprotein (HDL), smoking status and treatment for hypertension. The Framingham Risk Score attaches for both men and women a score to every of these variables and by taking the sum of these scores, it is possible to see what the percentage of 10-year cardiovascular risk of this individual is. To give an example, a woman who is 52-years old receives 6 point for her age variable. By adding the scores for all other variables, this could lead to a total of 17 points. This leads to a 5% 10-year risk for this certain individual (as you can see in Table 1), which means this woman has a 5% chance to suffer from a cardiovascular disease in the next 10 years.

The Framingham Risk Score is calculated by the following algorithm:

Step 1: Consider a multivariable model $f(Y) = \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_p X_p$, where Y is the 10-year risk percentage, X are the candidate risk factors and β are the estimates of the regression coefficients based on the appropriate regression model. These estimates have to be calculated.

Point Total	10-year risk (per cent)	Point Total	10-year risk (per cent)
<9	<1	17	5
9	1	18	6
10	1	19	8
11	1	20	11
12	1	21	14
13	2	22	17
14	2	23	22
15	3	24	27
16	4	25 or more	≥30

Table 1

Step 2: All different risk factors have to be organized in different categories. For age, this means we could get the categories 30-39, 40-49, 50-59, etc. In order to determine points for each category, we also need to specify for each category a reference value (W_{ij}). The mid-points are generally excepted, meaning that 34.5 is the reference point for the category 30-39 years. When the risk factor is a set of dummy variables, the reference value is simply 0. This means that for the variable gender, where we have two categories (female and male) the category we will use as base category will be assigned value zero and the other category will be assigned value 1.

Step 3: For every risk factor a base category has to be selected, which will get assigned 0 points. Categories reflecting worse states will get assigned more points, while categories reflecting healthier states will get assigned less points. In case 30-39 years has been chosen as the base category for age, this means $W_{1,REF}$ = 34.5 and all older categories will get a positive amount of points, since age has a negative effect on the cardiovascular risk.

Step 4: For all other categories it has to be calculated how far each category is from the base category in regression units. This means that for each risk factor this is equal to $\beta_i (W_{ij} - W_{i,REF})$. Since the estimated parameter for age (β_1) is 0.0575, this means that the distance for the category 40-49 will be: $\beta_1(W_{12} - W_{1,REF})$ = 0.0575(44.5-34.5) = 0.575.

Step 5: A constant B that represents the number of regression units that reflects 1 point in the final system will be calculated. In the Framingham points system, the constant is often based on age, which has been shown to be important and significant in most risk score functions developed in the Framingham Study. Often this constant has been set up to be equivalent to the increase in risk associated with a 5-year increase in age. This means that in our example B = 5 * 0.0575 = 0.2875, meaning that a distance of 0.2875 from the base value of a category is worth 1 point in the Framingham Risk Score.

Step 6: Now, the value calculated in Step 4 will be converted into an amount of points by dividing it by the constant B calculated in Step 5. This way every age group, which is 10 years older than the previous group, will get 2 points more than one age group lower.

Step 7: The amount of points will be converted to the probability of getting a cardiovascular disease in the upcoming 10 years. This will be done by attaching a risk estimate to each point using the multiple logistic regression function:

$$\hat{p} = \frac{1}{1+\exp\left\{-\sum_{i=0}^{p}\beta_i X_i\right\}}$$

In this formula β_i are the values of the estimates calculated in step 1 and X_i are the values of base categories chosen in step 3. All dummy variables will be left out in this formula, since they all have base value zero. This lead to an outcome that looks like Table 1, where the amount of points is converted to the probability of suffering from cardiovascular disease in the next 10 years.

Applications in different healthcare fields

The Framingham Heart Study is a good example where machine learning and statistical analysis are applied. But is definitely not the only study in the field of medicine where this is used. Developments in the application of machine learning in image recognition has made it possible for algorithms to detect and classify anomalies in various medical scans and images such as MRI scans and x-ray pictures. Notable research is done in aiding decision-making for skilled medical workers when observing a high number of scans, think of applications that assign colors to certain anomalies in MRI scans or select a subsection of important scans when checking every single one by hand would be too extensive for a human. Other research focusses on applying machine learning on drug discovery and development. An increasingly important role is reserved for machine learning in discovering new molecules or repurposing existing drugs for rare conditions. Antibiotic resistance is becoming more and more of a problem in recent decades, which makes the need for new antibacterial agents more pressing every passing year. Exploiting machine learning techniques in this field is already proving quite powerful in identifying these new agents in a faster and potentially cheaper way. The story of data science and statistical techniques in medicine is therefor not a book yet closed, however an always progressing and evolving one. More and better ideas are yet to come, only waiting to be discovered.

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Risk Factor	Categories	Reference Value	$\beta_i (W_{ij} - W_{i,REF})$	Points Assigned
Age	30-39	34.5 = $W_{1,REF}$	0	0
	40-49	44.5	0.5750	2
	50-59	54.5	1.1500	4
	60-69	64.5	1.7250	6
	70-79	74.5	2.3000	8
Gender	Female	0 = $W_{2,REF}$	0	0
	Male	1	1.3780	5

Table 2

A Trip Down the Memory Lane

Martijn Heinen

Started studies: 2010

Age: 27

With the seventh Lustrum of Asset | Econometrics still fresh in mind it felt unreal to receive an invitation to what would become the celebration of already 40 years Econometrics. As a few things changed in my life over the past five years, I noticed that the traditional components of a Lustrum were still present, including the ending with a Gala, which I – obviously – could not let pass by.

The evening started with a sit-down dinner at Villa de Vier Jaargetijden in Tilburg. Here, several tables were positioned and marked with a letter. The letter could be found back on the plane ticket received in the mail at home. (At least if your address is up to date, as some old members found out.)

At *boarding time* all present sat down at the tables where we were served with drinks and the waiters found out that they would not have a quiet night. Despite the advice from several tables the waiters were not allowed to put the wine bottles on the table, meaning they needed to walk around in order to ensure all with a drink. After two courses, starters and main, the clock approached 20.00 hours and given that the gala was on the May 4, it meant that we paid our tribute to the fallen soldiers by adhering to two minutes of silence.

Before the real party started and the rest of the guests would make their appearance we enjoyed a variety of desserts, some better than others, and an inspiring speech and word of thank you by our beloved Chairman.

Right after the dinner, the band started to play their set, but they forgot to align the volume of all microphones during the soundcheck. It was impossible to understand what the frontman was singing, even though each of the tracks was well known. Bottomline: the band did not leave a lasting impression and without even being noticed the band was being replaced by a DJ.

Nonetheless, more and more guests joined, which gave the opportunity to catch up with some members I had not spoken to for several years as well as with members that I encounter more frequent. While discussing personal matters, careers that were made - or already broken - time flew by without considering those indoors.

Throughout the whole evening a photographer was taking pictures of couples, and groups that wanted to eternalise the moment. Given the long line I would say: money well spent. For some reason taking pictures felt more appealing to the members being present than entering the dancefloor. Perhaps we are more related to Marketing than we care to admit.

Slowly, the end of the evening was approaching and although the gala would go on till 02.00 hours the bar personnel decided to stop pouring drinks way before. It required some negotiation power of the Lustrum Committee but after a while I was holding a drink again. However, all good comes to an end and the gala was no exception. Where some of the guest were discussing an afterparty in the centre of Tilburg, I made the decision that, given I left university a while ago, it would be wiser to leave for bed.

Lastly, I want to bring forward a special thanks to Stephan and Bob, who were so friendly to provide us with a place to sleep.


ASSET
Econometrics

Rabobank

Growing
a better world
together.

Rabobank

Rabobank is a bank that works for its customers and members. We are one of the largest financial institutions in the world, but we are still very involved at the local level. Our goal is to help customers achieve their goals. In addition, we aim to make a substantial contribution to the well-being and prosperity of people in the Netherlands and to a sustainable global food supply.

We are a bank with cooperative roots. Everything we do, we do together. With co-workers, members and other organizations. We believe in building on each other's strengths and making each other stronger. You get better results from working together than going it alone. Now and in the future. Partly we do this by developing complex models for different areas within the bank, like stress testing, IFRS 9, credit management, asset and liability management and risk management.

Rabobank: The Matlab to Python Journey

Risk management is everyone's business. It is in the heart of banking and has a key role in optimizing the risk/reward ratio. This is accomplished by assessing risks and creating a healthy relationship between risk and return. We use models to realize this and in this article we would like to tell you more about the transition from a Matlab based risk model landscape to one based on Python.

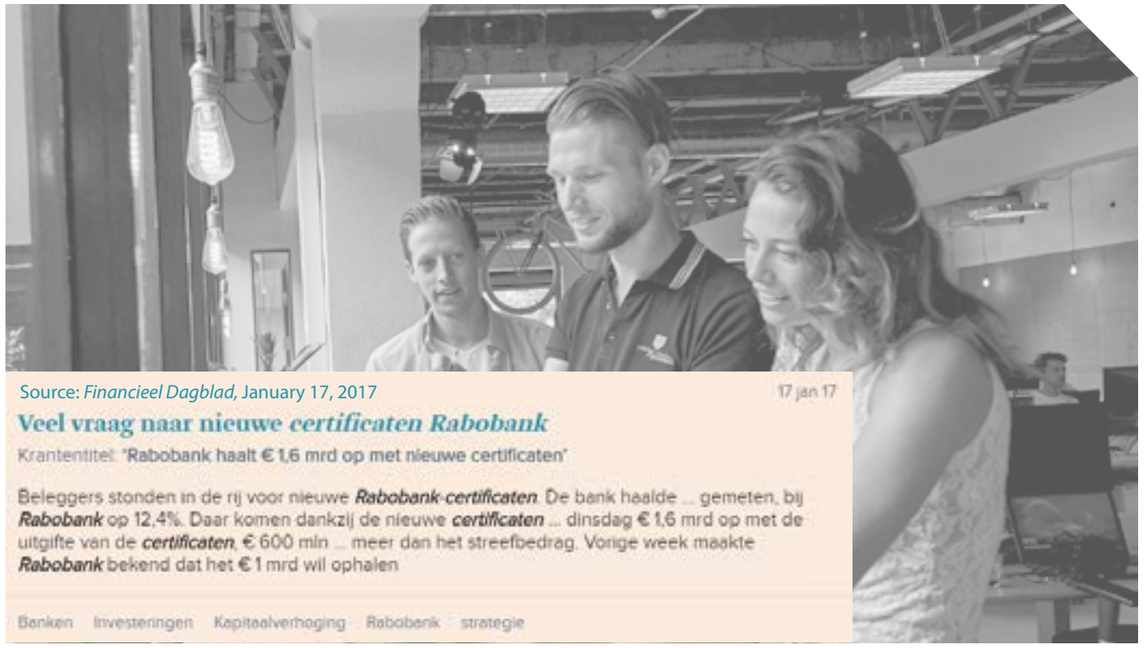
In the recent past, Matlab was the programming language of risk modelers within Rabobank. The software enabled the development of predictive models and the required data (pre-)processing using ready-to-use functionality combined with a rich and flexible programming language. The models developed could be validated and tested by an independent model validation team based on the Matlab code and the result files.

The biggest challenge emerged after the model was developed, validated, and approved: deploying it in professional IT systems of the bank. IT business analysts had the difficult job to understand and implement the complex calculation logic, and the data sourcing, into professional IT code (often C# or .NET). This step in the process was lengthy and error prone; user acceptance testing often revealed errors due to misinterpretations.

In 2017, we tried a different approach to a large scale modelling project. In cooperation with our IT department we agreed to implement the calculation logic in the popular open source programming language Python. This way, risk modelers could help in coding the complex calculation logic as part of the professional IT software. Instead of lengthy discussions to explain the tedious calculation steps, risk modelers deliver Python code that functionally does the job and that adheres to the most important IT software development standards.

This approach has turned out to be so promising we have adopted this as a standard way of working for all new risk models. Risk, data, and IT experts are working together in multidisciplinary Agile teams during the development of a new risk model. We now need less iterations to deliver the model in the production environment. Additionally, jointly developed calculation engines can be deployed more easily into the cloud to improve calculation performance.

We have made the transition complete by also migrating existing self-build Matlab library functions that were used during statistical modeling to in-house Python library functions for credit modeling. This code is optimized based on IT software development standards and designed for future use by other modeling projects.



Source: *Financieel Dagblad*, January 17, 2017 17 jan 17

Veel vraag naar nieuwe *certificaten Rabobank*

Krantentitel: "Rabobank haalt € 1,6 mrd op met nieuwe certificaten"

Beleggers stonden in de rij voor nieuwe ***Rabobank-certificaten***. De bank haalde ... gemeten, bij ***Rabobank*** op 12,4%. Daar komen dankzij de nieuwe ***certificaten*** ... dinsdag € 1,6 mrd op met de uitgifte van de ***certificaten***, € 600 mln ... meer dan het streefbedrag. Vorige week maakte ***Rabobank*** bekend dat het € 1 mrd wil ophalen

Banken Investeringen Kapitaalverhoging Rabobank strategie

The Journey from a Matlab Modeler Perspective

The vast majority of the risk modelers within the bank have been trained extensively in Matlab during their university days. But a modeler is a modeler and coding is coding, so migrating from Matlab to Python is not rocket science.

Nevertheless, the transition we are going through is an exciting one. Not because it is changing the language in which we program, but because it is changing and improving the technique in which we code (e.g. object oriented, writing tests). Another interesting part of the transition is working in so called Feature teams (multidisciplinary Agile teams). All of this leads to very nice personal growth opportunities.

Recently, Rabobank started to build a model in Python which will be used to assess the impact of strategic decisions on the financial performance of the bank, such as the profit and losses and the capital ratios. The current tool (which is even Excel based!) is being widely used within the bank. A publicly known example of this is the issuance of one billion euros worth of Rabobank certificates. Since the bank is migrating towards Python and Python is such a diverse programming language, there is even a possibility to build a complete web app in Python. This means that even members of the managing board can do analyses on their iPads while traveling to their next appointments. The web app will be hosted in the cloud and the model will be designed in such a way that the calculations can be distributed over multiple resources (e.g. virtual machines, cores, etc). All of this allows 'traditional' risk modelers to go beyond their traditional tasks. The same holds for the 'traditional' web app builder because of the multidisciplinary teams. Compared to the 'traditional' Matlab/Excel work, a whole new world opens up in this project.

Develop your professional impact

Do you want a career in which you can start making a difference from day 1? Rabobank is the place to do it. For instance, in a team making a new model based on the new approach using Python. Or, as an expert who does the implementing of the models in collaboration with the business departments. At Rabobank, we help you to be the best and most effective version of yourself.

Your development is key and we invest in an environment where you learn by doing. Already know what you want to do? We'll give you the space and opportunity. Still figuring it out? We can help. By providing a good balance between free-range and supervised work – with coaching and leadership that inspires you. Enjoy the safety net and network that a strong corporate employer has to offer, along with ample innovation capacity and flexibility.

What do you bring to the table? The right mindset:

Challenge: your peers and yourself
Connect: make new contacts and expand your network
Change: help transform yourself, the bank and the world
Courage: show initiative and perseverance

Everyone is different, and it is the differences in people that help us to be an even better bank. That is why we are curious about who you are! Let's get acquainted.

Would you like more information about the Young Professional Advanced Analytics Program or would you like to apply?

Please have a look at: rabobank.jobs/en/expertise/student-starter/ or rabobank.jobs/nl/young-professionals/

Gaining More Insight in Quantitative Investment

Jelle Thijssen

Bachelor EOR

Age: 21

On May 8, Asset | Econometrics visited Optiver at their office on the Zuidas in Amsterdam. The visit was initiated by the Quantitative Investment Group but was open for registration to all members with an interest in quantitative investing. Optiver is a company which originates from Amsterdam and are a globally leading electronic market maker today. A market maker provides liquidity to all kind of financial markets by at (almost) all times providing both a buying and a selling price for thousands, if not millions, of products on these markets. Optiver is specialised in market making for options.

After having some trouble with trains, we arrived at the office at about 13.45 hours. The program began with a general introduction of Optiver. The company's history, current philosophy and day to day business were explained. After this introduction we got a presentation by a trader, who gave us better insights in the tasks and daily routine of a trader. Every trader is appointed a certain market and is responsible for all trading done in this part of the market. Most trades are executed automatically by use of ultrafast computers and algorithms, but traders have to stay alert at all times. In case a peculiar event occurs, a trader must intervene as fast as possible, to ensure the algorithms does not make 'stupid' trades. We also got a presentation by a so-called 'execution trader'. This is an individual who has direct contact, mostly by phone, with large banks, insurers and investment funds. These financial institutions mostly trade 'blocks' (piles of financial products) which are many times larger than the trades handled by regular traders. The execution trader must be able to judge products and give prices for these large blocks very quickly by use of the information provided by his computer and the traders sitting around. For your illustration: executing traders have a desk at a central position surrounded by traders. Execution traders are also very important in pricing products, since large trades have a big influence on prices.

After these presentations, all participants got to do a numerical test, such that everyone got to put their mathematical skills to a test. The test that we got is the same as the test an applicant gets in the first round of his application. The test consists of 80 numerical questions which have to be solved within 8 minutes. (Most people don't finish the test.) To pass the test, one has to score approximately 50 points or more, where every correct answer is awarded with 1 point and error are sanctioned with 2 points deduction. Questions that are not filled in at the end are neglected. Several of the inhouse-participants got a sufficient score! Afterwards, we did a Market Making Game with a trader, which was a lot of fun. In the game, our group had to 'make a market' for a random good. For example, the first market we had to create was for the height of the trader presenting the game. Everyone could make a market by shouting a buy and sell price and others could jump in to sell or buy from the market maker. In the example's case a market could be 1.70@1.80. In the end, everyone's profits and losses were calculated and a price was awarded to the person with the highest profit.

After the game we got to take a look at the trading floor of Optiver. Every trader has a desk with two computers and 6 screens and all desks are aligned in long rows. It was quite impressive to see the traders at work. We finished the day at Optiver's own bar with beers, 8-ball pool and pizza.

We would like to thank Optiver for the interesting and exciting day!

Bas Dietzenbacher
is a research fellow within the International Laboratory of Game Theory and Decision Making at HSE University in St. Petersburg, Russia. From 2010 to 2018, he studied at Tilburg University and finished the Bachelor Econometrics and Operations Research, the Master Operations Research and Management Science, and a research Master and PhD program in Business, Operations Research.

The Cultural Capital of Russia

Besides many magnificent churches and cathedrals, Saint Petersburg is home to more than two hundred museums and theaters, including the famous Hermitage and the Mariinsky Theater. Although I am usually not a big fan of museums, opera, or ballet, I exploit the opportunity and spend a significant part of my large amount of free time to discover these art forms in the cultural capital of Russia.

Saint Petersburg plays a prominent role in Russian history and culture, being a place where many world-known musicians, painters, singers, writers, actors, and architects lived and worked. The historic center and related groups of monuments constitute an UNESCO world heritage site. The best known attraction is the State Hermitage Museum, the second-largest art museum in the world (preceded by the Louvre in Paris). It is said that if you spend one minute looking at each item of its collection, it would take you eleven years. Funnily, the museum is still home to a group of more than fifty cats, originally adopted to control the mice. To me, honestly, the architecture and decoration of its main building, the Winter Palace, are more impressive than the exhibits. A much more unknown favorite is Grand Market, an indoor miniature museum like Madurodam, presenting an image of everyday life in Russia with day/night effects.

More regularly, I visit the Mariinsky Theater for an opera or concert. Basically every day there are performances in all its main buildings: Mariinsky-I, Mariinsky-II, and the Concert Hall. The first one is an old and classic opera house, the second a modern and stylish one, and the third puts the orchestra on the main stage and is acoustically my favorite. The artistic director is Valery Gergiev, who was also the chief conductor of the Rotterdam Philharmonic Orchestra in the past. The main difference with the Netherlands is that there are many more performances and tickets are much cheaper: for fifteen euros you have a good place at a regular opera of three hours. The reason for this is that Mariinsky is heavily subsidized and salaries of performers are low. For opera and ballet, I also like to go to the smaller Mikhailovsky Theater, and for symphonic concerts to the Philharmonia, hosting the Saint Petersburg Philharmonic Orchestra and the Saint Petersburg Symphony Orchestra. Unfortunately, Russia is not as familiar with wind orchestras as the Netherlands is especially in the south. This means that I paused playing the saxophone for the time I live here. This will be a reason to go back to the Netherlands in the future.

Saint Petersburg also has a permanent circus theater. Although I do not like the use of animals in such shows, I really enjoyed the acrobatic part. Since I do not speak Russian, it is less interesting to go to cinemas, but once I watched an English movie with Russian subtitles there. The hall was incomparable to any Pathé I have seen, furnished with high curtains, separated luxury armchairs, and even statues. Most of the theaters in the city are actually drama theaters, but I have not been able to find a play in English so far. For the time being, this is not a reason for me to start learning Russian. I considered buying a ticket for a drama play just to take a look at the hall, since many theaters and museums are located in buildings of former palaces. Since 2018, Saint Petersburg is actually home to the highest building of Europe: the Lakhta Center. Unfortunately, the observation deck is still closed, and since I deeply admire tall buildings, I cannot wait for the opening!

The Individual Settlement Allocation Procedure

A mutual liability problem comprises a network of interacting economic agents. Consequently, these agents have mutual liabilities as well as assets to be used for monetary transactions. If all agents want to settle their claims, the question at hand is how to allocate the total assets among them. To this end, agents can use the Individual Settlement Allocation Procedure, where agents act on their own and yet reach a consensus on the allocation.

written by **Martijn Keetelaars**

Mutual liability problems

The notion of a mutual liability problem is perhaps best explained by means of an example with three agents. For the sake of expositional convenience, these agents are Alice, Bob and Charlie, i.e. $N = \{Alice, Bob, Charlie\}$. Alice, Bob and Charlie are mutually indebted, which can be represented by a *claims matrix* $C \in \mathbb{R}_+^{N\times N}$, where element $c_{i,j} \in C$ indicates the claim of agent j on agent i. With regard to this example,

$$C = \begin{bmatrix} 0 & 1 & 2 \\ 1 & 0 & 1 \\ 5 & 2 & 0 \end{bmatrix}.$$

For instance, Alice owes 1 to Bob and 2 to Charlie, however Alice has a claim of 1 on Bob and a claim of 5 on Charlie. In addition to this, each of them owns assets, which are represented by an *estate vector* $E \in \mathbb{R}_+^N$, where element $e_i \in E$ indicates the estate belonging to agent $i \in N$. Alice has an estate of 2, whereas both Bob and Charlie have an estate of 1. That is, $E = (2, 1, 1)$.

Suppose that Alice is running short of money and thus asks Bob and Charlie to pay off their respective debts of one and five euros to her. Even though Bob is able to do so, Charlie can only pay her at most one euro. Therefore, he turns to Alice and Bob and demands that they pay him back. Alice can pay off her debt of two euros to Charlie, but Bob does not have enough and consequently asks Alice and Charlie to pay him. Alice pays Bob one euro which Bob uses to pay Charlie. At this point both Alice and Bob are debt-free and Charlie owns 4, i.e. $E = (0, 0, 4)$. Unfortunately, this is still insufficient for Charlie to pay off his debts. Therefore the assets in this network are insufficient for all claims to be settled. This gives rise to the following question: how should the total available amount of assets in this network be allocated among the agents, while taking the mutual liabilities of all agents into account?

On solving mutual liability problems

If you are familiar with *bankruptcy problems*, you might have noticed that mutual liability problems are a generalization of such problems. In a bankruptcy problem there is a single non-negative estate, e, that has to be allocated among a finite set of claimants, N, where each claimant $i \in N$ has a non-negative claim, c_i, on the estate. In order to determine an allocation of the estate, one can make use of so-called *bankruptcy rules*. Such rules prescribe for each bankruptcy problem how to allocate the estate among the claimants. To put it mathematically, let $\mathcal{B}^N$ denote the set of all bankruptcy problems (e, c) on N, where N denotes a finite set of agents. A bankruptcy rule $\varphi\colon \mathcal{B}^N \to \mathbb{R}_+^N$ assigns to each bankruptcy problem $(e, c) \in \mathcal{B}^N$ a non-negative allocation $\varphi(e, c) \in \mathbb{R}_+^N$ such that

$$\sum_{j\in N} \varphi_j(e, c) = \min\{e, \sum_{j\in N} c_j\},$$

and $\varphi_j(e, c) \leq c_j$ for all $j \in N$.

Groote Schaarsberg, Reijnierse and Borm (2018) present a method of solving mutual liability problems that makes use of a so-called *payment matrix*, which is a non-negative matrix $P \in \mathbb{R}_+^{N\times N}$ where element $p_{i,j} \in P$ indicates the payment of agent i to agent j. These payments are derived through bankruptcy rule φ. A formal definition of φ-transfer schemes is given below.

Definition 1. *Let $(E, C) \in \mathcal{L}^N$ and let φ be a bankruptcy rule. For all $i \in N$ let $\bar{c}_i$ indicate the i-th row of claims matrix C. Then the matrix $P \in \mathbb{R}_+^{N\times N}$ is called a φ-transfer scheme for (E, C) if*

$$p_{i,j} = \varphi_j(e_i + \sum_{k\in N} p_{k,i}\ ,\ \bar{c}_i) \text{ for all } i, j \in N.$$

Thus, the amount agent $i \in N$ has to pay to agent $j \in N$ is determined by the solution of the bankruptcy problem agent i faces with estate equal to the current estate of agent i plus what agent i receives from other agents, and with claims equal to the claims on the estate of agent i.

The set of all possible φ-transfer schemes for $(E, C) \in \mathcal{L}^N$ is denoted by $\mathcal{P}^\varphi(E, C)$. Groote Schaarsberg et al. (2018) show that there always exists at least one φ-transfer scheme. Therefore, on the basis of these payments $P \in \mathcal{P}^\varphi(E, C)$ they define the φ-transfer allocation α^P. That is, for $i \in N$ the allocation is equal to

$$\alpha_i^P = e_i + \sum_{j\in N} p_{j,i} - \sum_{j\in N} p_{i,j},$$

so the allocation to agent $i \in N$ equals the estate plus the net payments of agent i. Interestingly, Groote Schaarsberg et al. (2018) show that for $\bar{P}, \hat{P} \in \mathcal{P}^\varphi(E, C)$ it holds that $\alpha^{\bar{P}} = \alpha^{\hat{P}}$. Hence, all φ-transfer schemes that correspond with a mutual liability problem give the same allocation.

Nevertheless, a drawback of working with φ-transfer schemes is that solving it by hand can be quite complicated even for problems with three agents. This is due to the fact that a system of dependent equations has to be solved; and in order to do so, one often needs to exploit characteristics of the problem and properties of the bankruptcy rule φ. In the situation of Alice, Bob and Charlie as discussed in the previous section, the following set of equations has to be solved:

$$(p_{1,1}, p_{1,2}, p_{1,3}) = \varphi(2 + p_{2,1} + p_{3,1}, (0, 1, 2)) \qquad \text{(Alice)}$$
$$(p_{2,1}, p_{2,2}, p_{2,3}) = \varphi(1 + p_{1,2} + p_{3,2}, (1, 0, 1)) \qquad \text{(Bob)}$$
$$(p_{3,1}, p_{3,2}, p_{3,3}) = \varphi(1 + p_{1,3} + p_{2,3}, (5, 2, 0)) \qquad \text{(Charlie)}$$

In addition to this, Groote Schaarsberg et al. (2018) make quite a restrictive assumption. They assume that an independent autohority is assigned the task to allocate the total estate among the agents. This assumption can cause their solution method to fall apart. For instance, if Alice does not want to disclose her debts, then there will be no consensus about the allocation. Alice's privacy is more important to her. In spite of this, agents can take matters into their own hands instead and still reach a consensus on how to allocate the total estate among them.

Individual Settlement Allocation Procedure

The *Individual Settlement Allocation Procedure* is a recursive procedure put forth as a solution to the complications the φ-transfer scheme approach brings about. This procedure states that agents settle their claims individually which ultimately leads to a unique allocation. More specifically, in each step each agent uses the same bankruptcy rule to allocate his estate among the others. Therefore agents make payments to each other, which implies that the total estate is reallocated. In addition to that, these payments lower the mutual liabilities. The result is a new mutual liability problem to which the same procedure can be applied. This process can either go on indefinitely or terminate at a point where no agent makes any further payments. However, even if payments go on indefinitely, it can be shown that the sequence of estate vectors that is generated by the Individual Settlement Allocation Procedure has a finite limit. Hence, there always exists a unique allocation.

In order to illustrate this procedure, suppose that Alice, Bob and Charlie apply the *proportional rule PROP*. This rule divides the estate among the claimants proportional to the claims and is defined by

$$PROP_i(e, c) = \frac{c_i}{\sum_{j\in N} c_j}\, e \qquad \text{if } \sum_{j\in N} c_j \geq e.$$

Otherwise, $PROP_i(e, c) = c_i$ for all $i \in N$. Hence, in the first step

$$PROP(2, (0, 1, 2)) = (0, \frac{2}{3}, 1\frac{1}{3}), \qquad \text{(Alice)}$$
$$PROP(1, (1, 0, 1)) = (\frac{1}{2}, 0, \frac{1}{2}), \qquad \text{(Bob)}$$
$$\text{and } PROP(1, (5, 2, 0)) = (\frac{5}{7}, \frac{2}{7}, 0). \qquad \text{(Charlie)}$$

For instance, this means that Alice pays $\frac{2}{3}$ to Bob and $1\frac{1}{3}$ to Charlie. Subsequently, reallocate the total estate and reduce the mutual claims by the payments:

$$E^2 = \begin{pmatrix} 2 \\ 1 \\ 1 \end{pmatrix} + \begin{pmatrix} 1\frac{3}{14} \\ \frac{20}{21} \\ 1\frac{5}{6} \end{pmatrix} - \begin{pmatrix} 2 \\ 1 \\ 1 \end{pmatrix} = \begin{pmatrix} 1\frac{3}{14} \\ \frac{20}{21} \\ 1\frac{5}{6} \end{pmatrix},$$

>>

and

$$C^2 = \begin{bmatrix} 0 & 1 & 2 \\ 1 & 0 & 1 \\ 5 & 2 & 0 \end{bmatrix} - \begin{bmatrix} 0 & \frac{2}{3} & 1\frac{1}{3} \\ \frac{1}{2} & 0 & \frac{1}{2} \\ \frac{5}{7} & \frac{2}{7} & 0 \end{bmatrix} = \begin{bmatrix} 0 & \frac{1}{3} & \frac{2}{3} \\ \frac{1}{2} & 0 & \frac{1}{2} \\ 4\frac{2}{7} & 1\frac{5}{7} & 0 \end{bmatrix}.$$

Therefore, in the second step Alice has sufficient funds to fully pay her remaining debts. On the other hand, Bob and Charlie do not. Thus,

$$PROP(\frac{20}{21}, (\frac{1}{2}, 0, \frac{1}{2})) = (\frac{10}{21}, 0, \frac{10}{21}), \qquad \text{(Bob)}$$

$$\text{and } PROP(1\frac{5}{6}, (4\frac{2}{7}, 1\frac{5}{7}, 0)) = (1\frac{13}{42}, \frac{22}{42}, 0). \qquad \text{(Charlie)}$$

Again, reallocate the total estate and reduce mutual claims to get

$$E^3 = \begin{pmatrix} 2 \\ \frac{6}{7} \\ 1\frac{1}{7} \end{pmatrix}, \quad \text{and} \quad C^3 = \begin{bmatrix} 0 & 0 & 0 \\ \frac{1}{42} & 0 & \frac{1}{42} \\ 2\frac{41}{42} & 1\frac{4}{21} & 0 \end{bmatrix}.$$

At this moment, Bob can pay off his remaining debts while Charlie still cannot. Charlie first allocates $1\frac{1}{7}$ by giving $\frac{40}{49}$ to Alice and $\frac{16}{49}$ to Bob. Finally, Charlie will only receive one more payment of $\frac{1}{42}$ from Bob which he will allocate among Alice and Bob. Bob's payment is still not sufficient, so ultimately Charlie goes bankrupt. Therefore, the limit of the sequence of estate vectors is attained in a finite number of steps and can shown to be equal to $(2\frac{6}{7}, 1\frac{1}{7}, 0)$. Thus, the Individual Settlement Allocation Procedure prescribes that in this case Alice receives $2\frac{6}{7}$, Bob receives $1\frac{1}{7}$, and Charlie receives 0.

Unlike the previous example, payments can also go in indefinitely such as in the following mutual liability problem:

$$E = \begin{pmatrix} 1 \\ 1 \\ 1 \end{pmatrix}, \quad \text{and} \quad C = \begin{bmatrix} 0 & 1 & 1 \\ 1 & 0 & 1 \\ 0 & 0 & 0 \end{bmatrix}.$$

Suppose all agents apply the proportional rule. The proportional rule prescribes that in each step agents 1 and 2 allocate their estate equally among their claimants, while both only receive half of that amount back. Moreover, agent 3 does not make any payments at all.

Therefore, agents 1 and 2 ultimately pay

$$p_{1,2} = p_{1,3} = p_{2,1} = p_{2,3} = \frac{1}{2}\sum_{k=0}^{\infty}\frac{1}{2^k} = \frac{1}{2}\frac{1}{1-\frac{1}{2}} = 1.$$

Thus, the allocation is equal to

$$(1,1,1) + (1,1,2) - (2,2,0) = (0,0,3).$$

An interesting relationship

In contrast to the φ-transfer scheme approach of Groote Schaarsberg et al. (2018), the Individual Settlement Allocation Procedure partitions the original bankruptcy problem each agents faces into a — possibly infinite — series of sub-problems that are solved separately. There is a particular property of bankruptcy rules that allows you to partition a bankruptcy problem without changing the allocation. This is the *composition up* property defined below.

Definition 2. *Let $(e,c) \in \mathcal{B}^N$. A bankruptcy rule φ satisfies* composition up *if*

$$\varphi(e,c) = \varphi(e',c) + \varphi(e-e', c-\varphi(e',c)),$$

for all $0 \leq e' \leq e$.

One can show that for the class of bankruptcy rules that satisfy the composition up property, the resulting allocations of both discussed solution methods coincide. In other words, agents are not obliged to disclose their debts in case such bankruptcy rules are applied. As a matter of fact, one can show that the proportional rule satisfies composition up. Therefore, for any mutual liability problem $(E,C) \in \mathcal{L}^N$ it holds that

$$\alpha^P = \lim_{k\to\infty}\{E^k\},$$

where $P \in \mathcal{P}^{PROP}(E,C)$ and $\{E^k\}$ is the sequence of estate vectors generated by the Individual Settlement Allocation Procedure in which agents apply the proportional rule.

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Martijn Ketelaars
Research Master

A Company Day Where I Did Not Quite Ace a Case

Abdel Zariouh
Bachelor EOR
Age: 22

The second event of the lustrum week was the company day, where all Bachelor and Master students could register and six companies were invited. This event took place at the alluring location De Phil where we were welcomed with coffee, tea and worstenbroodjes. Unfortunately, I already had breakfast so I had to leave them on the plate. After this welcome everyone was kindly asked to go to the plenary gallery for the General Opening of the day.

Mathijs Jansen, former board member of TEV and currently Senior Consultant at Anago, was the main speaker of the General Opening, where he informed us about his experience of the sixth lustrum ten years ago. He started his board year together with four other enthusiasts with the evident goal of finishing it with five board members. After a couple of months two board members already decided to quit their journey and the board was left with only three members. They responded by opening a new application round in order to reinforce the team. This resulted in no students applying for a position. After this, they decided to ask two students, who were good friends with each other, to apply for a board position. They agreed to taking on this challenge. All board members experience their board year as a roller coaster, but Mathijs should have been in a even crazier roller coaster experience during this.

After the General Opening, the first two cases and one training were given by Achmea, Deloitte and Rabobank. The training organized by Rabobank was open for first- and second-year students. I participated in the case of Achmea together with around fourteen other students in their end-phase of their studies. The Achmea case started with a general talk about Achmea, so that everyone was informed about their core business and working environment. After this, they presented us the case where we had to valuate a reinsurance contract of different pay out layers. For this we first had to select one of three methodologies: the Burning Layer method, the Empirical CDF method and the Extreme Value Theory method. For each method they had some data available for us. After discussing which method to select for far too long, we chose the Empirical CDF method. We had no clue how to perform this method so we kind of gave our own interpretation to this. This resulted in a valuation that was way too high compared to the other two groups and the actual answer.

After the case a lunch break was scheduled with delicious sandwiches and orange juice. Here we could network with the company present. As a true nerd I approached one of the representatives of Achmea to ask them how I was supposed to ace the case. Now I know how to value this kind of contracts, so just call me if you happen to end up in a situation where you have to do this as well.

During the second round, Pipple organized the training and Rabobank and Capgemini organized the cases. I joined the Capgemini case where we again were welcomed by a general talk about Capgemini. Then they presented their case about writing a piece of code that could count the frequency of a word in large text. Together with Joris Piree, I started with installing Matlab in order to write the code. However, after some minutes we realized that this was not the best strategy to win the case, so we decided to start RStudio. By googling we found a function that could check if two strings match. The only thing we had to do now is to loop over the words in the text and check how many words match. Unfortunately, due to technical issues, we were not able to present any results but we bluffed our way of this. I think we did well on this.

We finished the day by an informal dinner with Capgemini, Milliman, Pipple and Rabobank. There were stands were you could get your meal and you could network and eat with the representatives of the companies. The burgers were absolutely fantastic so a big shout out to the Lustrum committee for this!

Young and Successful, Still Distances to Go

written by **Lucas Jacobs**

On a Wednesday afternoon, Jeffrey and I interviewed dr. Anne Balter at her room in the Prisma building. Some econometrics students may know here from the IFAS course taught in the 1st year of the Bachelor or from the Empirical Finance course taught in the Master's study program as a core course of QFAS. Currently Anne is only 29 years old, which makes her the youngest assistant professor here in Tilburg. She has been working for 3 years in Tilburg now. Since her student life is still not yet that far away in the past, Jeffrey and I hope to have an interesting interview with her where we can communicate on the same level.

Studies

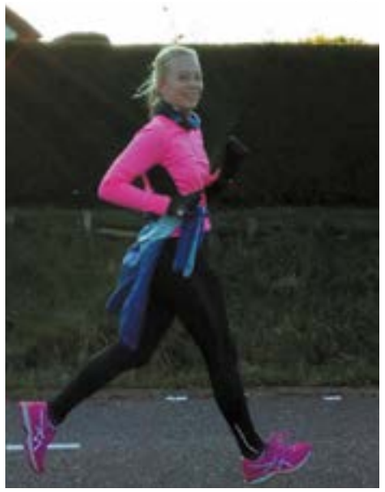
Anne was born in Sittard which is a city in the South of the province of Limburg (in the Netherlands) while she lives in Hoensbroek, also in Limburg. She is not married. After finishing high school cum laude, she studied EOR at the Maastricht University. The reason for studying EOR is that she wanted to do something which would involve mathematics and the choice for the Maastricht University is because there you are obligated to go abroad during your studies: this international nature was/is very appealing to her. The Problem Based Learning (PBL) concept of this university, although this was not her main reason to choose for Maastricht, where students have to work in small groups during tutorials, is given a positive note by Anne because of the active learning component of this concept. Here the tutorials are more important than the actual lectures. Also for both her Bachelor studies and her Master studies Anne graduated cum laude.

During her student time she was an active member of the study association Vectum which is the equivalent of Asset, although Vectum is somewhat smaller than Asset. During the last half year of her Bachelor's study and her Master's study she was also a working student at the Actuarial Department of AZL, which is a smaller competitor of APG. She studied Actuarial Sciences partly because she worked at AZL. When Anne went abroad for her studies, she went to the University of Queensland which is in Brisbane, Australia: quite far away from home. A beautiful environment and lots of travelling through Australia have characterized this exchange for her. Concerning the studies done there by Anne: as econometrician from the Netherlands, the courses and tests there are not too hard.

An academic career

During her Master studies a professor at the university proposed to Anne to do a PhD, Anne agreed to this and she did a PhD on the topic of model uncertainty which relates to all fields of EOR: mathematical finance and also some operations research among other things. During this time, Anne came into contact with Netspar which makes the link between academics and the pension sector, more about this in just a few lines. During her PhD time, Anne also had her own consultancy company for a short while, Anne Balter Consultancy (ABC), for an actuarial project in mortality experience research and cost modelling for AZL. This was the result of the fact that people at AZL, who still knew Anne from her working student time at that company, often approached her to ask for advice regarding certain questions about the impact of changing term structures and regulations among other things. Anne is currently a researcher for Netspar investigating pension related questions that arise in the sector or by policy makers such as the minister of social affairs. She writes papers for Netspar, sometimes with other people from the university. She has also talked with various parties that are involved in the pension reform plans for the Netherlands. This is extensively in the news as there is a discussion going on in the Netherlands on a pension reform, here one can clearly see the impact of theoretical research on society: econometrics researchers, including Anne, make their calculations and write their advisory reports. In the end, however, the politicians of course need to decide. Anne's research is not only about the pension sector though but is, just like her PhD, linked to all kinds of EOR fields. The reason why she has chosen for Tilburg University to pursue her research has also to do with this: the econometrics department of Tilburg University is a broadly diverse team which is not commonly encountered at other universities, even worldwide.

In the last year of the PhD one has to send, among other documents, application letters to universities worldwide that have a vacancy open. This is all centrally arranged so the universities receive the documents at the same time, you can then be invited for an interview by a number of universities which will all be held in the same place: in Anne's case this was at a place in San Francisco in the United States. Within a few weeks one hears for which universities one is invited, then there is a "fly-out" to these universities: this means an intensive/



very busy day in which one gives seminars and talks with the people of the relevant department. At last one has multiple offers from different worldwide universities and a choice has to be made. In this way Anne also had the interview with Tilburg University in San Francisco which would eventually lead to her working at this university.

Staying efficient

We as econometricians do a lot of sitting and thinking all day of course, sometimes even up to the point that we become inefficient and sluggish. Just like we as students need to take our mind off the mathematics from time to time, the teaching and research done by the university employees requires breaks from time to time. Anne often fills these breaks and some of her spare time by long distance running. She is quite fanatical/competitive in this, she trains for distances up to a marathon, which is a distance of approximately 42km. She recommends running especially to econometricians, both when one is still studying or already working in the business world or academia.

> " The econometrics department of TiU is a broadly diverse team "

Because of our relatively theoretical mindset, running has a positive effect on structuring one's mind. But one could also use running to overthink difficult problems and sometimes even solve them while making kilometers according to Anne. The longer distances and more intense interval trainings can be used to really focus on increasing the speed of your feet and body, thus clearing our minds. Afterwards one can go back to the desk/computer and look into the problem sets with a more fresh view. Of course not only the sport of running is suitable for clearing one's mind, although it is the mother of all sports and it is relatively easy done. Think of it in this way: most of our careers as econometricians involve working long on irregular days or travelling which makes running very suitable as you can bring your shoes wherever you go nor are you tied to specific training hours.

But the running for Anne does not stop at just usual breaks or regular spare time, one of her favorite hobbies is to combine running competitions with holidays. In the context of bettering the virtue of integration, participating in these running competitions brings you closer to the locals so that they will see you as less of a tourist. There are some remarkable instances for Anne in regards to this hobby. Anne has participated in "die schönste Marathonstrecke der Welt": the so-called "Jungfrau" marathon which is one of the most well-known marathons in the world which takes place on a mountain in the Swiss alps. And yes one has to walk up the mountain not down, the finish is at 2095 altitude meters (meters above sea level) at the bottom of the glacier in Switzerland.

Another instance was when she was visiting the Nobel prize winner Lars Hansen, which we as good econometricians should know all too well of course (the GMM guy), at the University of Chicago for her research. She combined it with a visit to the capital of the state of Tennessee (to the South of the state of Illinois), namely Nashville, to participate in its half marathon which takes you through some of Nashville's most beautiful and historic scenery. Anne also likes cycling and hiking: she has travelled from the Netherlands to Santiago de Compostella which is a city in the northwest of Spain all by bike which is around 2500km with a small tent taken along as luggage. The trait of sporting entrepreneurship can therefore not be denied to Anne in any way.

Lastly, another hobby of Anne is playing the alto saxophone in an orchestra (Dutch: "harmonie") which seems to be quite popular in the South of Limburg. "Top 40" songs, classical music, film music, blues among other music types: such an orchestra plays all kinds of music. The orchestra in which Anne plays is not some stereotypical "old lady gang" but instead a very young group where many of her friends are playing too. At the moment, however, Anne does not have so much time anymore to rehearse and can therefore only join in for carnaval.

All in all, our final impression of Anne is that of an intelligent, sporty and ambitious assistant professor here at our econometrics department in Tilburg. We wish her all the best in furthering her career and exercising her hobbies as described in this article.

dr. Anne Balter

Bert & Ernie Questions

Bert/**Ernie**
Australia/Netherlands
Canada/Netherlands
Company/**University**
Fries/**Pizza**
Using a calculator/Mental calculation
Beer/Wine

70 Warlike Econometricians Battling for Victory

On March 11, at 20.00 hours, the registrations for the Active Members Weekend, abbreviated AMW, opened. This moment had been written in my agenda with three exclamation marks for several weeks already, since last year three minutes after the registrations went open all spots were already taken. This year, the capacity of the weekend had increased from 60 to 70 participants, a 16.7% increase for those interested. The consequence was that the tremendous pleasure of joining this weekend could be given to even more econometricians.

After we all were assigned to a group, the preparations could begin. Since we only had one month to prepare our outfits and our team flag, a little rush was needed. Many things had to be done, and we took our task very seriously. The theme of this year's AMW was games, and to every team a specific game was assigned. Some games that were portrayed this weekend were Zoo Tycoon, Mario, Sonic and Barbie learns how to ride her horse. To my group one of my favorite games was assigned, namely Angry Birds. It was very difficult to come up with a good outfit for this theme, and after multiple sessions of brainstorming via WhatsApp, and after some sleepless nights, we finally came up with the brilliant idea to dress ourselves like birds, and then look angry. I had the honor to be the red bird. My teammates, Hugo, Niels and Janne were the yellow, black and green bird, respectively. Since two fellow birds dropped out unfortunately, we were only left with four. Then the biggest present that we could ever have imagined was given to us: Maarten. To him, the honor was given to be the blue bird.

About a month later, on a beautiful sunny Friday morning, the moment was there. After a decent breakfast of bread, a banana for both Hugo and me, champagne and some healthy orange juice (mixed with a little vodka to add some flavor) the moment we had been working to for a month had arrived: AMW 2019. About 70 econometricians assembled near the swimming pool of Stappegoor. From this moment, the race was on. Friendships of several years turned out to be worthless, and the true nature of econometricians arised: wild cavemen hungering for victory. It turned out that we had to do a so called 'crazy 88' in the beautiful city of Breda. With a clenched fist, and a beer in the hand, we all traveled to Breda. Here we did several things to earn as many points as possible for your team. Examples of things we had to do were a handstand against a wall, helping the elderly when crossing the road (as econometricians are very social, responsible people), buying pickles for Mylan, who was sitting outside a café, buying chocolate for Mylan, still outside that café and playing a game of Mario Kart against Tjum, in another hospitality establishment and then buying a beer for Tjum. It became clear how hard the committee had to work in order for the weekend to be a success. For this a big bravo to the committee.

When the sun was slowly setting, we went to our location. As the day passed, we received hints from which the location became clear. As econometricians like puzzles, for many these hints were the best part of the weekend. Unfortunately, we were not able to solve the riddle, so the location was given to us: Alphen. Our hearts leapt for joy when we heard this, because we really loved the idea of spending the weekend in Alphen. We were not the only econometricians in the bus when going to Alphen. We sang many songs along the way. This made the way to Alphen even more pleasant. There were also non-econometricians in the bus. We did not ask them whether they liked our songs, but looking at the smiles on their faces when we left the bus, I think they were still enjoying our music.

The evening at our location in Alphen was really special. For every team a bucket was filled with a mix of drinks, including Malibu, and we had to drain the bucket using straws. Some of us liked the drink, including me. Others however disliked it a little. This is very unfortunate of course, but it is always difficult to create something to everyone's taste. At least, the committee did their best. After having dinner, and playing some games, it was time for the famous AMW cantus. As last year, this cantus was not as well-structured as a regular cantus. As an econometrician, I love structure, so this hurt a little. Still, we all had a wonderful evening, and night.

The next day me and many other econometricians were woken up by Tjum. He was yelling that he was going to wake us up in thirty minutes. We were all exceptionally grateful for this announcement, as we now knew for how much longer we could have slept. During the second day, we played several games. One of these games was playing a kind of Game of the Goose, well-painted by Mylan. Another game was the econometricians version of thirty seconds. We also played the game 'Who am I?', in which one player has a paper with the name of a fellow econometrician on his or her forehead, and then he or she has to guess who this is person is, by asking questions. Other games required more physical action. We went to the woods for instance, all team members attached to one another by means of a rope, a part of the team blindfolded, and then we had to find the flags of other teams. This was great fun.

In the meantime, the crazy 88 went on. We jumped over fences, swam in the grass, made a pile of ourselves, ate crackers as fast we could and pretended to be a postman all in order to receive as many points as possible. During the day, many beer games were played too, like 'fuck the dealer', with minigames! Especially the minigames, and the enthusiasm of the players made it a huge success. We all liked to drink with each other, because we are each other's mates. And when we drank with each other, we took our time to enjoy our beers. In the evening, we went into town, to a bar. It was quite a long walk, so we sang many songs along the way, like songs by Nick and Simon, my personal favorites. The time we spent in the café was also nice. The place was bigger than the one of last year, at least there was room for all of us. Additionally, the drinks were not too expensive. In the café, there were many middle-aged people partying too, aside from Quirien. For me, this was an extraordinary thing to see, not something I am used too. However, everyone has right to their pleasure, and so do they.

The next day, on Sunday, it was time for the moment we had all been waiting for: the ranking of the teams. I do not remember the spot we finally landed on, but given the amount of energy and effort we put into this weekend, it must have been in the top 3. It would not surprise me if we won the competition. If only I remembered. Unfortunately, some cleaning had to be done too on Sunday. Quirien, as is tradition for the chairman of Asset | Econometrics, had to clean the bathroom. After cleaning, we went back to Stappegoor again. Here, we did some hangover swimming. For many, this was the end of AMW. However, for a small group of diehards, including myself, we ended AMW with a dinner somewhere back in Tilburg.

Then already, AMW had come to an end. Everyone went back home: it was time to rest. It has been a wonderful weekend for everyone, and I would like to thank the committee for organizing this beautiful weekend, and a special thanks to the Angry Birds team, for being so energetic, ambitious and enthusiastic, and for fighting for victory until the bitter end.

Ricardo van Belzen

Bachelor EOR

Age: 21

INFORMS Student Team Competition Finals – Texas, 2019

written by **Martin Faro and Tijn Fleuren**

This year, a team consisting of two Research Master students in OR (Aras Selvi and Lorenz Roebers), one QFAS Master student (Niek Simons) and two BAOR Master students (Tijn Fleuren and Martin Faro) participated in the INFORMS O.R. & Analytics Student Team Competition. From October until January, this team worked under the magnificent supervision of Dr. J.C. Vera Lizcano on a real-life problem provided by General Motors (GM), the title sponsor of the event. The competition problem asked students to help analyze how autonomous vehicles may change the finished vehicle and delivery operation process for GM. A record-breaking amount of 292 teams from over 25 different countries participated in the event.

In March, the six finalists were announced: Hankuk University of Foreign Studies (Republic of Korea), Hebrew University of Jerusalem (Israel), KAIST (Republic of Korea), University of Belgrade (Serbia), University of Maryland University College (USA) and Tilburg University. From April 9 to 18, the team from Tilburg traveled to Austin (Texas, USA) to present during the prestigious 2019 INFORMS Business Analytics Conference. In this article, two members of the team (Tijn Fleuren and Martin Faro) will share their experiences.

The journey to Austin

Our journey started back in October 2018 when the team captain, Aras, contacted us to join the team. Last year, Lorenz and himself had just missed out on a spot in the finals and were eager to make it to the last six teams during this edition. We thought this would be a perfect opportunity to put the skills, which we have gained during the Bachelor and Master courses, into practice. The problem was of such complexity that we really had to split the workload in the first phase. After that, we started to work fully as a team to put the pieces together. During the last few weeks before the final entry had to be delivered, we literally worked day and night (since Aras does not have the typical Dutch sleeping habits) to really solve the problem. Due to the diverse backgrounds of our team, every team member could excel in one or more key aspects of the project. At the end of January, we finally completed the report and handed in our final version. We knew that we had to wait until March 4 before we would know whether we were one of the six finalists. We could not be any happier when we received an e-mail on March 3 with the following subject: "INFORMS Student Competition: Selection as Finalist".

As a finalist, we were given the opportunity to travel to Austin to give a presentation on our project for a selected panel consisting of GM's management and academic experts. In the weeks between the finalists announcement and our travel, we practiced the presentation over and over. We were even given the opportunity to present at the O.R. Seminar on March 21. The feedback from the most prominent professors from Tilburg University with a background in O.R. really helped us to prepare for the questions we could expect in Texas. A special word of thanks should be given to Dr. Juan Vera Lizcano, who supervised us intensively during the entire project and helped us to make the final adjustments to our presentation.

The trip to the USA

On April 9, we (Martin and Tijn) traveled together with Aras Selvi, the team captain, to Houston. The first few days we stayed in an AirBNB and explored the fourth biggest city of the USA. We visited several highlights of this enormous city, such as the NASA headquarters. Everybody will recall the phrase "Houston, we've got a problem!". We traveled by Uber to visit the different parts of the city, which provided us with the opportunity to get to know the real Americans. During these days, we met a lot of very interesting and kind people. After three days in Houston, we moved to Austin by Greyhound (a not so particularly nice bus located in a not so particularly pleasant neighborhood). Since ground travel in the USA is indeed not of the same quality as the European standards, this was an interesting experience. In Austin, we met our other two team members, Lorenz and Niek, who could not join us earlier due to obligations in Tilburg. After they had recovered from their jetlag, we explored the city of Austin on April 13. We visited the Texas capitol, the Bullock Texas State History Museum and went to the Congress Avenue bridge to look at the nightly bat spectacle, when 1.5 million bats emerge after the sunset. Unfortunately, the bats didn't come out that day…

The competition

On April 14, the INFORMS Business Analytics Conference started. In the morning, we were given a final opportunity to rehearse our presentation. After this rehearsal, we had the opportunity to visit the different workshops that were part of the conference. Personally, we visited the technical workshops from Matlab and AIMMS (a little bit of loyalty, since we have been using these softwares for years in Tilburg). There was also a large career fair, where we spoke to several recruiters from America-based companies. After dinner we had a session with the management of GM and met the other finalist teams. It was interesting to hear their stories and see the differences in team setup: we appeared to be the youngest ones around. We decided to go home on time, as we had to wake up early the next day to give the final presentation.

April 15, 9.40 hours. This time had been engraved in our memory for more than a month. This should become our moment to shine. After the opening by our team captain, Aras, Niek and Tijn Fleuren gave an excellent presentation. The questions were tackled with relative ease by our entire team. After 20 intense minutes, we walked out the room with a satisfied feeling. Unfortunately, we had to wait for more than 24 hours before the final results would be known. In the meantime, we had the opportunity to visit talks from academicians as well as practioneers. We felt a little bit disappointed that we had to miss the session of Dick den Hertog on Robust Optimization, which took place at exactly the same time as our presentation. We were however able to visit a lecture by Dimitris Bertsimas on Interpretable AI, which was closely related to decision trees covered in Master courses such as "Decision Making with Business Analytics" and "Data Science Methods". At the end of the day, the famous Franz Edelman price, the summum in the field of O.R., was awarded during the Edelman banquet, for which we also had received an invitation. This year, the team of Louisville Metropolitan Sewer District and Tetra Tech won the prestigious prize. We felt proud that Tilburg University was appearing on screen as one of the winners in previous years. (In fact, it is the only institution in the world which has received this prize twice, red.)

The last day of the conference, during lunch, the ceremony for our competition was held. As Americans typically like to orchestrate such an event in detail, we were asked to arrive in time and practice the ceremony. After that, while enjoying some nice food, we waited to be called to the stage to hear the final judgements. Some of the teams were very nervous at that point. We did not really share this feeling, since we were already proud to be there and satisfied with our performance during the final presentation. In the end, unfortunately, we did not end up in the top 3, but we were given an honorable mention with the following nice words: "Clarity of their presentation and the usefulness of their approach in trading off performance and speed in the solution." Afterwards, a bunch of pictures were taken, some of which are quite nice (see below).

Juventus-Ajax and thank you

Before ending this article, there is one final nice thing to mention. During the last day of the conference, after the ceremony, we visited some company stands. Two of these were from AIMMS and Ortec, which we met earlier during the conference. Due to the difference in time, the game Juventus-Ajax was already being played in the afternoon for us. We were taking some pictures with the people from AIMMS when one of their colleagues arrived with a laptop broadcasting the game. With a group of around ten people we watched the final 30 minutes of the game and cheered (a little bit too loud) when Ajax scored and won in the end.

We think it has already become clear from this article that we really enjoyed the trip to Texas. It was an honor to be selected as one of the six finalists out of so many teams from all over the world and to represent Tilburg University in this competition at the conference. We would like to thank the university for its great support. Also, a special thank you to INFORMS, General Motors and all the other sponsors for organizing such an interesting and challenging competition. Lastly, a very warm word of gratitude to our team advisor, Juan Vera, whose advice and support were instrumental in attaining all of this.

From left to right: Tijn Fleuren, Martin Faro, Aras Selvi, Terry Cryan (INFORMS), Niek Simons and Lorenz Roebers.

Epidemics, Vaccines and Mathematics

Infectious diseases have had an enormous impact on the course of human history. Various epidemics have killed hundreds of millions of people, and some diseases have been responsible for the depopulation of large areas. One would expect that reliable vaccines for deadly diseases are met with nothing but approval and appreciation. Instead, vaccination rates are dropping recently due to controversy and the spread of misleading information. This raises the question: what can math tell us about epidemics and vaccination?

written by **Stefan ten Eikelder**

The antivax community has caused quite a stir in the world of epidemiology. A 1988 British study falsely concluded that the MMR (measles, mumps, and rubella) vaccine caused autism in 8 out of 12 patients in the study. Later, it turned out that the researcher involved falsified the data and the results were debunked. Nevertheless, the results sparked an increase in the antivax movement, and the connection between vaccines and autism is still upheld by many people. An increasing number of people who refuse to vaccinate their children leads to an increase in the probability of new epidemic outbreaks, and is thus cause for major concern among healthcare experts.

We refrain from the political discussion, and focus on the math. We will introduce the most popular mathematical model for the spread of infectious diseases, and we will analyze how vaccinations can prevent an epidemic and eradicate the disease.

The SIR model

In 1927, the seminal work of Kermack and McKendrick [1] introduced the SIR model. This is a so called compartmental model, as it splits the population in three groups/classes: Susceptible (S), Infected (I) and Recovered (R). An individual is susceptible if (s)he has not (yet) been exposed to the disease, infected if currently carrying the disease, and recovered if they have cleared their infection. It is assumed that individuals who have recovered have gained immunity to the disease. An individual in class S moves to class I once infected, and an individual in class I moves to class R once they have fought off the disease.

The standard SIR model is deterministic, and assumes a homogeneous population. Hence, the change in any compartment size can be described by a partial differential equation (PDE). Let N denote the population size and let X, Y and Z denote the number of individuals in classes S, I and R, respectively. The alert reader will notice that we implicitly assume that the infectious disease does not have a substantial mortality risk. Since an analysis of deadly diseases is more complicated, we focus on benign (non-deadly) diseases.

Suppose an individual makes k contacts with other individuals per unit of time. Then, during a small time period of length δt, the individual has contact with $kY/N\delta t$ infected people. Suppose that the probability of succesfull disease transmission is c. Then, a susceptible individual does not get infected during this time period with probability

$$1 - \delta q = (1-c)^{kY/N\delta t},$$

so δq is the probability of infection for these contacts. With an extra definition, $\beta = -k\log(1-c)$, we can rewrite the previous equation to

$$\delta q = 1 - e^{-\beta\delta t Y/N}.$$

Now, we expand the right hand side using the Taylor expansion and divide both sides by δt. Subsequently, we take the limit $\delta t \to 0$ to find

$$\frac{dq}{dt} = \beta Y/N.$$

This is the rate at which a susceptible individual gets infected. Then the rate of transmission for the entire susceptible class is given by

$$\frac{dX}{dt} = -\beta XY/N.$$

With slight abuse of notation, we let S, I and R indicate the *fraction* of the population in these classes, so $S+I+R=1$. Then the transmission rate for the S class is

$$\frac{dS}{dt} = -\beta IS,$$

Figure 1: Some news headlines indicating the decline of vaccination rates.

the parameter β is known as the transmission rate parameter, and $1/\beta$ can be interpreted as the time between contacts with disease transmission. The SIR model is given by

$$\frac{dS}{dt} = -\beta SI \tag{1a}$$
$$\frac{dI}{dt} = \beta SI - \gamma I \tag{1b}$$
$$\frac{dR}{dt} = \gamma I, \tag{1c}$$

where γ is the recovery rate of infected individuals. That is, $1/\gamma$ is the duration of an infection. The model (1) cannot be solved analytically. Nevertheless, we can simulate the progression of the disease. An example is displayed in Figure 2, where initially a single individual is infected and at the peak 70% of the population is infected. It is important to note that in model (1) the disease will eventually die out due to the fixed population size.

The threshold phenomenon

Despite the simplicity of the SIR model, it provides a crucial insight into the factors that determine whether or not there will be a proper epidemic outbreak. We can rewrite (1b) to

$$\frac{dI}{dt} = I(\beta S - \gamma).$$

Then, if $\frac{\beta}{\gamma}S(0) > 1$ we have $\frac{dI}{dt}(0) > 0$, so the number of infected people initially increases. The ratio $\frac{\beta}{\gamma}$ is known as the basic reproductive number R_0. This is the number of new infections created by an infected individual. The basic reproductive number plays a crucial role in epidemiology for the following reason. For many infectious diseases it is reasonable to assume that initially the entire population (except the first infected individual) is susceptible, so $S(0) = 1-\epsilon$. Then the disease spreads if $R_0 \geq 1$ and dies out if $R_0 < 1$. This is known as the *threshold phenomenon*, first discovered by [1]. The higher R_0, the faster the disease spreads and the hard it is to control. Table 1 provides R_0 estimates for various diseases.

Disease	R_0
Influenza	3-4
Rubella	6-7
Chickenpox	10-12
Measles	16-18

Table 1: Estimates of R_0 for various infectious diseases, taken from [2].

Modeling life and death

Before we move to vaccinations, we add birth and (non-disease related) death dynamics. For our simple deterministic model, we assume a lifespan of $1/\mu$ years, so μ is the rate of birth and death. Newborns enter the system as susceptible, and deaths can occur in all classes. The SIR model with demographics now reads

$$\frac{dS}{dt} = \mu - \beta SI - \mu S \tag{2a}$$
$$\frac{dI}{dt} = \beta SI - \gamma I - \mu I \tag{2b}$$
$$\frac{dR}{dt} = \gamma I - \mu R. \tag{2c}$$

We can derive the basic reproductive number R_0 for this model in a similar fashion as in the previous section:

$$R_0 = \frac{\beta}{\gamma + \mu}.$$

Compared to model (1), this model allows for analysis of the long term behavior of the disease in the population, due to the inclusion of birth-death dynamics. Two equilibria can be determined, by simply setting the right-hand side expressions in (2) to zero. For (2b) we find that either $I^* = 0$ or $S^* = \frac{\mu+\gamma}{\beta}$. The former leads to the *disease-free* equilibria:

$$(S^*, I^*, R^*) = (1, 0, 0),$$

and the latter leads to the *endemic* equilibria:

$$(S^*, I^*, R^*) = \Big(\frac{1}{R_0}, \frac{\mu}{\beta}(R_0 - 1), 1 - \frac{1}{R_0} - \frac{\mu}{\beta}(R_0 - 1)\Big).$$

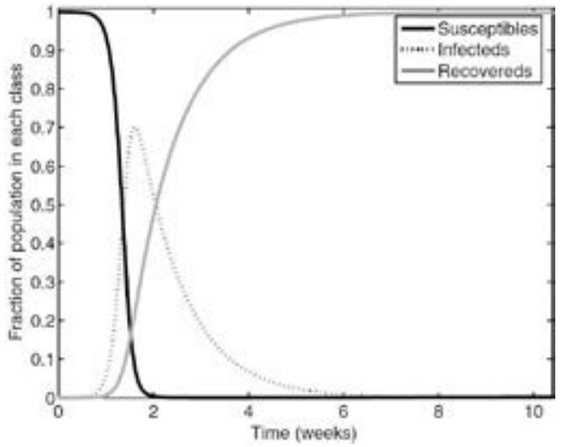


Figure 2: Simulation of model (1) for $\beta = 1.428$ per day (520 per year) and $1/\gamma = 7$ days, initially a single individual is infected. Image taken from [2].

Because the population variables must be nonnegative, the endemic equilibria is only possible if $R_0 \geq 1$. Hence, we again observe the threshold phenomenon.

Vaccinations to the rescue

Suppose a fraction p of the population is vaccinated at birth via a so-called pediatric vaccination program and that vaccination confers lifelong immunity. This can be modelled by letting vaccinated newborns enter the system in the recovered class (which is essentially an immune class) instead of in the susceptible class. Non-vaccinated newborns still enter the system in the susceptible class. The SIR model with vaccination reads

$$\frac{dS}{dt} = \mu(1-p) - \beta SI - \mu S \tag{3a}$$

$$\frac{dI}{dt} = \beta SI - \gamma I - \mu I \tag{3b}$$

$$\frac{dR}{dt} = \gamma I + \mu p - \mu R. \tag{3c}$$

We are now in position to analyze the influence of the vaccination rate p. In [3] the following variable substitution is proposed: $S = S'(1-p)$, $I = I'(1-p)$ and $R = R'(1-p) + p$. Then model (3) is equivalent to

$$\frac{dS'}{dt} = \mu - \beta(1-p)S'I' - \mu S' \tag{4a}$$

$$\frac{dI'}{dt} = \beta(1-p)S'I' - (\gamma + \mu)I' \tag{4b}$$

$$\frac{dR'}{dt} = \gamma I - \mu R. \tag{4c}$$

One can recognize that (4) in fact has the same structure as model (2), the only difference is that β is replaced by $\beta(1-p)$. Let R_0' denote the vaccination corrected basic repopulation number. Then we must pick the fraction p such that R_0' is below 1. With β replaced by $\beta(1-p)$, we get

$$\frac{\beta(1-p)}{\gamma + \mu} < 1 \Leftrightarrow p > 1 - \frac{1}{R_0}.$$

Hence, to eradicate a disease, it is crucial to vaccinate at least a fraction $p_c = 1 - R_0^{-1}$ of the newborns. Of course, vaccinating more than p_c will make sure the disease is eradicated more rapidly. It is now straightforward to calculate the critial proportion p_c for the diseases in Table 1. The fact that it is not neccesary to vaccinate all newborns is known as *herd immunity*: non-vaccinated (susceptible) individuals are protected from infection because they are surrounded by a sufficient number of vaccinated individuals.

Reality: Heterogeneity, imperfect vaccines and noise

The simple SIR model provides some fundamental insights in the spread of disease and the influence of vaccinations. However, it makes quite a few assumptions, which limit the direct applicability of the model. In particular, it assumes a non-deadly disease. Furthermore, it assumes a homogeneous population (with fixed lifespan and infection duration), vaccines providing lifelong immunity and a deterministic disease spread. Many variations on the SIR model have been developed to deal with these limitations [2]. In particular, stochastic differential equations are a proper tool to add many of these components to the model.

Math is at the heart of epidemiology, and provides crucial insights into the effects of various vaccination strategies. In the current political debate on vaccines, its importance will probably not die out soon.

References

[1] W.O. Kermack and A.G. McKendrick (1927). A contribution to the mathematical theory of epidemics. Proceedings of the Royal Society of London. Series A 115(772) 700–721.

[2] M.J. Keeling and P. Rohani. (2008) Modeling infectious diseases in humans and animals. Princeton University Press

[3] D.J.D. Earn et al. (2000). A simple model for complex dynamical transitions in epidemics. Science, 287(5453), 667–670.

Rage Cage with Minigames with Siblings of Econometricians

Malu Sieben

Jelle's Sister

Age: 23

Monday, May 20. Because I made a miscalculation in my time schedule, I arrived about half an hour later than planned (oops) at Building E. My 'little' brother Jelle gave me a super quick tour of 'de kamers'. "People can buy sweets and drinks here. We have our meetings here. Here is my desk." It is nice to know where he spends most of his time when he is not in a bar. "And now we have to hurry to the brothers and sisters day," he says. And he was right. As soon as we got there, the activity started. It began with a presentation about activities within Asset, such as the Lustrum and the 'leuke' International Business Tour to Seoul last year. It was apparently very 'leuk' - at least, Wenxin seemed to think so. She even made me enthusiastic to go! (Do you need to study econometrics to be allowed to go on these International Business Tours? You do? Hm.. Is it possible for the next brothers and sisters day to take place in Seoul or Mexico City? No? Can anyone fit me in their suitcase? Please?)

After these presentations, everyone walked to a field nearby. Except Jelle and I, who were lazy – or efficient? - and took our bikes there. We were divided in teams and played different games with the promise of a prize for the best team. Our team started with a game of life-size table football, where I may have stepped on someone's ankles in my fanaticism (so sorry about that).
After the game of football, we went on to Rage Cage, where we discovered, after five minutes, that we were supposed to be somewhere else: it was our turn to play mega Beer Pong with buckets, but without beer. I have to be honest, though, and note that my teammates did the most of the work here: I never managed to throw the ball in a bucket. Every time someone on our team threw the ball in a bucket, we got a minigame. The first game was matching pictures of Asset members to pictures of their brothers/sisters. Since I do not really know anyone except Jelle, I felt completely useless. The next game was 'Juffen' to 30, which Jelle tried to sabotage by telling everyone not to say 7, 11, 14, 17, 21, 22, 27 and 28. That did not help, since we only made it to 14 anyway. The third minigame was a numeric puzzle, where you had to come up with the missing number. I confidently told everyone that the answer was 33, but Nina said that answer was wrong. She ended up double checking, and it turned out there were two possible solutions, so we still got the points! (Yay!)

After Beer Pong, we went to Rage Cage, where we were – this time - supposed to be. I had never played Rage Cage before, but thankfully Jelle and Rick were real experts. They scored most of the points for our team, I lost most of the points for our team. I blame the wind. (Okay, maybe I just sucked, but I did score the winning point!)
The only game left to play was Kubb, where you basically throw sticks at blocks. Jelle amazed all of us by throwing the stick in such a graceless way, but hitting the target exactly. I managed to hit a girl with my stick (also sorry about that).
I think that everyone gave their best at the games and had a lot of fun, I know I did. After the games, we moved to the sports café. The BBQ there was very tasty and everyone was eating and chatting, the vibe was really nice. By the time everyone had eaten enough and Quirien really could not manage to get rid of the 'speklappen' anymore, the winners of the game activity were announced. I am 23 and of course too old to care about these things. Moreover, it is about participating and not about winning. I obviously do not care. But our team did win! (Ok, so I care, but who cares?)

Thanks Asset | Econometrics and thanks Jelle, for a super nice day! I already look forward to the next brothers and sisters day!

Quatsch!

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Quatsch?

Over the past few months, the editorial staff of Nekst received many quotes that relate to the study of Econometrics and to the activities organized by Asset | Econometrics. Hereby, we present to you a selection of some striking and funny quotes!
Please mail all remarkable quotes you have heard to Nekst@Asset-Econometrics.nl!

Pierre Verhulst
Denk niet in problemen, drink in oplossingen

Loes van der Linden
Coenraad is net iets minder dan de helft van mij

Erwin van Oosten
Je kan beter je hypotheek aftrekken dan je kind

Linda Torn
Weet je hoe lekker mijn zoons gaan zijn?

Dominique Bavelaar
Zelfs Greenpeace komt in actie als er nu niet meer gekapt wordt

Anouk Verhagen
Maar ik ben wel goed met mijn mond

René Peeters
Je moet vooral zorgen dat je een vrouw uitzoekt met gebreken, dan kom je er zelf beter van af!

Puzzle

vs

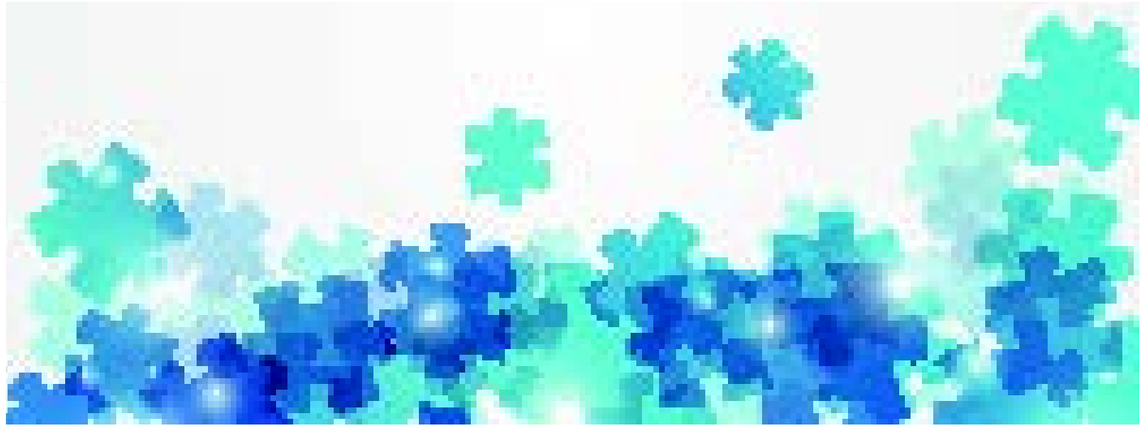
Quirien and Denise play 'rock, paper, scissors' ten times. Given is:

- **Quirien chooses stone three times, scissors six times and paper once;**
- **Denise chooses stone twice, scissors four times and paper four times;**
- **no draw occurs;**
- **the order in which Quirien and Denise make their choices is unkown.**

Who wins? And what is the score?

Can you figure out the puzzle?
Please enter your solutions at www.Nekst-Online.nl/Puzzle. A crate of beer or a delicious pie, whichever the winner prefers, will be waiting for whoever has sent the best (partial) solutions. Please note that, as before, every recipient of this magazine is eligible to send in their solutions, so members of the department are invited to participate as well. Good luck!

Bas Ramaekers is the winner of the previous puzzle. As a reward, he can come and pick up a crate of beer or a pie at room E1.10. The solution can be found at www.nekst-online.nl



Asset | Econometrics congratulates...

Name **Kunyue Wang**
Title Application of Least Squares Monte Carlo in the Calculation of Prices and Sensitivities for Credit Valuation Adjustments of Bermudan-type Options
MSc QFAS
Supervisors Dr. N.F.F. Schweizer, Prof.dr. B.J.M. Werker

Name **Tom Scholtze**
Title Purchase time estimation using survival models - An e-commerce case study
MSc EME
Supervisors Dr. B. Drepper, Dr. J.R. de Bresser

Name **Karlijn Canjels**
Title A Method for Analyzing Complex Hospital Processes based on process and data mining tools
MSc BAOR
Supervisors Dr. K. van Deun, Dr.ir.ing. M.J.P. Peeters

Name **Manuel Bastin**
Title Machine scheduling problem with setup times applied to a practical case on order processing by laser cutting machines
MSc BAOR
Supervisors Prof.dr.ir. R. Sotirov, Prof.dr. A. Ghaffari Hadigheh

Name **Shayekh Hassan**
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MSc BAOR
Supervisors Dr.ir.ing. M.J.P. Peeters, Dr. J.C. Vera-Lizcano

Name **Ezgi Özgül**
Title A General Framework for Logistics Network Design, which Provides Re-optimization Capabilities When Performing a "What-if" Analysis
MSc BAOR
Supervisors Prof.dr.ir. H.A. Fleuren, Dr. Y. Merzifonluoglu

Name **Jerom Theunissen**
Title Predicting stress at work (Data analysis using machine learning techniques)
MSc EME
Supervisors Prof.dr. B. Melenberg, Dr. J.R. de Bresser

Name **Mattijs Veneman**
Title Infrastructure Games (Establishing fair tariffs for shared use of infrastructure from a game theoretical perspective)
MSc EME
Supervisors Prof.dr. P.E.M. Borm, Prof.dr. H.J.M. Hamers

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Title A wind direction based stochastic weather generator
MSc BAOR
Supervisors Dr. G. Gürkan, Dr. M. Rothfelder

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Supervisors Dr. R.L.P. Hendrickx, Prof.dr. B. Melenberg

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MSc BAOR
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Name **Milan van der Kamp**
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MSc BAOR
Supervisors Prof.dr. H.J.M. Hamers, Prof.dr. H.W. Norde

Name **Jasper Mol**
Title A guide to Sensitivity Analysis within ASML
MSc EME
Supervisors Prof.dr. K.J.M. Huisman, Prof.dr. P.M. Kort

Name **Felix Gulinck**
Title Yield curve extrapolation using the Nelson Siegel model and no arbitrage affine models
MSc QFAS
Supervisors Dr. O. Boldea, Dr. F.C. Drost

...on obtaining their Master's degree

Summer Photo Contest

The rules are simple and the title explains a lot already: send in your best summer picture featuring at least one Asset | Econometrics related object to win a crate of beer or a pie. Submissions can be send to nekst@asset-econometrics.nl or in the suitable Facebook group upon announcement of our beloved board. An example submission is attached below. We encourage you to at least reach this level of creativity. Good luck!

Agenda

TUE 27 AUG **Monthly Afternoon**
Now that the summer holiday is over and all freshmen are recovering from the TOP week, make sure to come to our first Monthly Afternoon of this year to catch up with your fellow econometricians and meet the new freshmen!

MON 02 SEP **Tilburg University Cantus**
The start of a new academic year also means it's again time for the yearly Tilburg University Cantus! All active members are welcome to join us to this legendary event. We only have limited spots available, so make sure to save the date!

WED 04 SEP **Introduction Activity**
Meet your fellow econometricians and make new friends at the Introduction Activity! The Introduction Activity committee is already working hard to organize the games and activities for this day, so stay tuned...

TUE 10 SEP **Department Members' Meeting**
We would like to invite all of our members to the Department Members' Meeting, where the board of Asset | Econometrics 2019-2020 will officially be constituted. During the meeting the current board will discuss the ins and outs of the past year and the new board will present their policy for the academic year 2019-2020.

TUE 10 SEP **Constitution Drink**
After the DMM we will celebrate the constitution of the new board and thank the current board, consisting of Quirien, Wenxin, Jelle, Nina and Joris, for their efforts in the past year!

TUE 13 SEP **Sports Activity**
Do you want to keep up that summer body? Luckily for you, the Sports committee has an activity in store for you to start the new year in a healthy way!

TUE 18 SEP **EOR Business Dinner**
At the EOR Business Dinner, you have the opportunity to get to know several companies in the field of Econometrics and Operations Research better whilst enjoying a lovely three-course dinner. During each course you will sit with a different company and we will end the evening with a networking drink such that you can meet all of the participating companies throughout the evening. All third-year Bachelor students and Master students are welcome to join us!

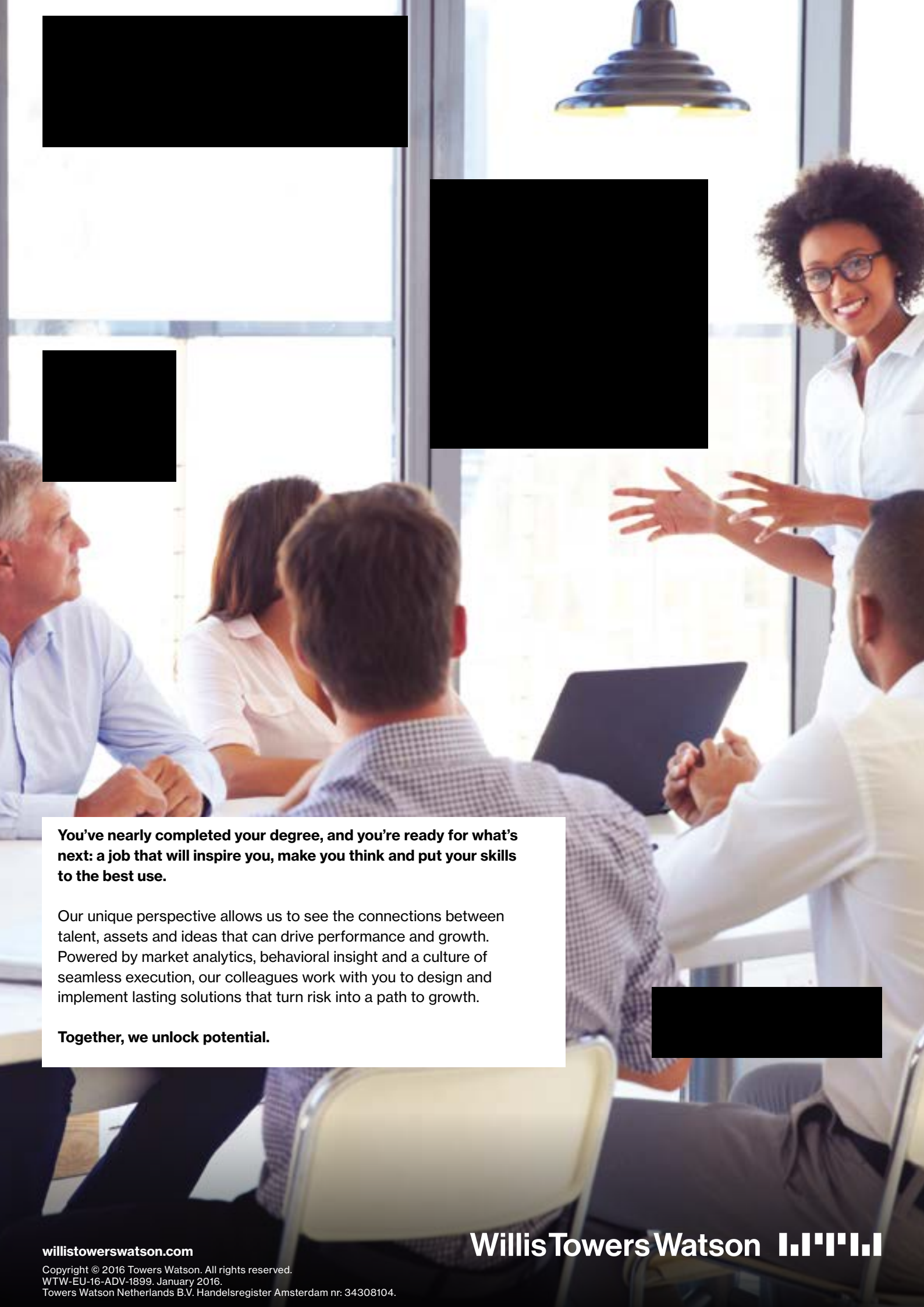
FRI 20 SEP – SUN 22 SEP **Freshmen Weekend**
Get to know your fellow first-year students (even) better through lots of fun activities at the Freshmen Weekend! The location and activities of the weekend will remain a secret for now, but we promise you it will be a weekend never to forget!

THU 26 SEP **LEST**
Do you want to meet econometricians from other universities and challenge them in a game of sports? Then this is the perfect event for you! The LEST is the national sports event for econometricians. We will participate with several teams so let us know if you want to join us!

FRI 01 OCT **Hackathon Tilburg**
This year it is finally time for our very first Hackathon! In cooperation with study associations Asset | SBIT and D.S.A. Pattern, we will organize a 24-hour hackathon in Tilburg for all Tilburg University students interested in Artificial Intelligence and Data Science. The hackathon will revolve around the subject of sustainability. Keep an eye on our website for more information!

WED 09 OCT **Banking Day**
To all Tilburg University students interested in Banking, Corporate Finance and Merger & Acquisitions; this event is the perfect opportunity for you! We will visit two top banks in the Netherlands where we will have a program with a presentation, case and lunch or drink.

Register and find more information about our events at
www.Asset-Econometrics.nl/events



You've nearly completed your degree, and you're ready for what's next: a job that will inspire you, make you think and put your skills to the best use.

Our unique perspective allows us to see the connections between talent, assets and ideas that can drive performance and growth. Powered by market analytics, behavioral insight and a culture of seamless execution, our colleagues work with you to design and implement lasting solutions that turn risk into a path to growth.

Together, we unlock potential.

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