Two proposals to transfer some risks related to the carrying of avocado loads

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José Daniel López-Barrientos[1]   Ana Pamela Flores-Herrera[2]
Ernesto Fernández-Arias[1]   Beatris Adriana Escobedo-Trujillo[3]

[1]Facultad de Ciencias Actuariales
Universidad Anáhuac México

[2]Facultad de Comunicación
Universidad Anáhuac México

[3]Facultad de Ingeniería
Universidad Veracruzana

Facultad de Ciencias Actuariales

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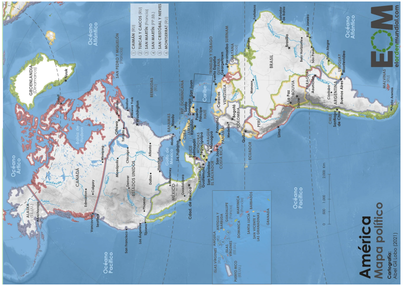
Problem statement

Where does your guacamole come from?



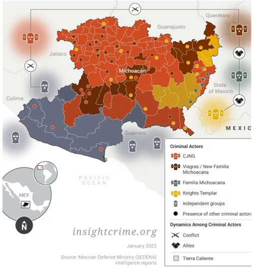
A duck-shaped continent. Source: [3].

The “Place of Fish”. Source: [18].

Order *vs.* Chaos

1. Preparation of soil	**6. Transportation to packing facilities**
2. Sowing	7. Emballage
3. Adding manure and fertilizers	**8. Transportation to export ports or domestic transportation**
4. Irrigation	9. Distribution in retail, wholesale stores, and other sale points.
5. Harvesting	10. Consumption

Table 1: Logistics of the production of *aguacates*.



Distribution of criminal cartels on Michoacán. Source: [1].

Two partial solutions

Hors-route
We use mean-field game theory-like methods to solve a nonzero-sum game on a system of interacting objects and thus propose a method to maximize the market share of the owners of the packing facilities under a long-run criterion.

On the highway
We apply a contingent claims technique to price a financial instrument for funding highway insurance for the transportation of basic materials.

Goals of the research

General goal

Identify affordable methodologies to:

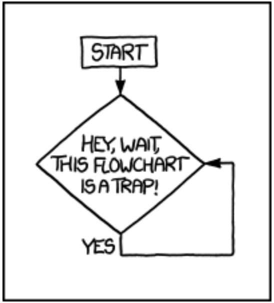
- Compute the fair price of a toll road insurance investment.
- Encourage the competition among packinghouse owners to facilitate access to *aguacatero* orchard owners.

Infographic obtained from here.

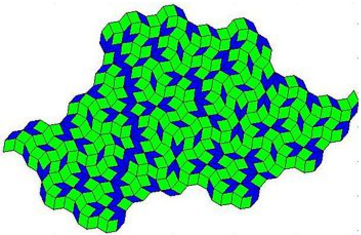
Picture obtained from here.

Specific goals.

- Isolate algorithms that allow carrying out the valuation of highway insurance.
- Elaborate examples under theoretically accessible hypotheses.



Algorithm obtained from here.



Tessellation obtained from here.

Theoretical framework

Importance of *L'or vert du Mexique*

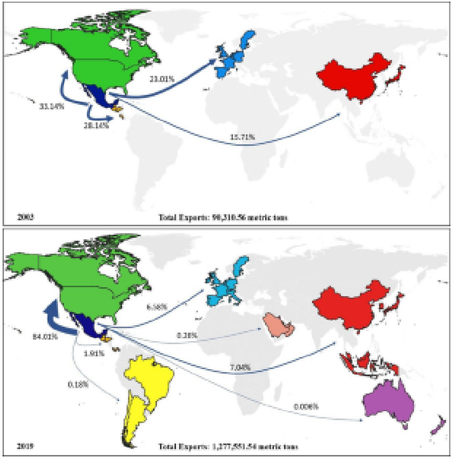


Figure 1: Michoacán is the most important producer of *palta* in the world. Source: [6].

Key facts

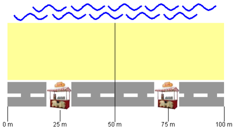
According to section 7.3 in [5],
No national program grants credits, nor fiscal incentives to motivate the owners of the packing companies to bring their businesses closer to the producers.

A member of the APEAM, who is also an orchard owner, said
a truck (with 9T of fruit) drives for up to 4h to get to a packing facility from orchards, and none of the 84 *emballage* firms has more than one packing house.

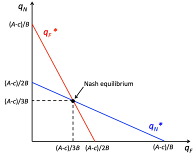
Felony	Cases per 100,000 inhabitants
Extortion	5050
Kidnapping	1982
Car theft	1775
Robbery	1801

Table 2: Felonies related to piracy. Source: [19].

The State-of-the-Art

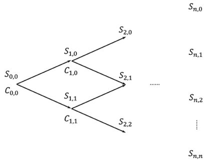


(a) Hotelling's model (see [10]). Image borrowed from here.



(b) Cournot's competition (see [11], [13], and [16]). Image borrowed from here.

(c) Abelian Theorems (see [14]). Image by P. Camargo Bacha.



(d) Contingent claims approach from [8], mixed with simulations from [15]. Image borrowed from here.

Methodology and results

Covering piracy acts *hors-route*

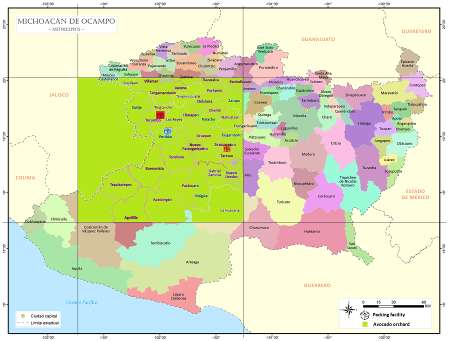


Figure 3: Location of *Persea Americana* producers, along with **three** packing companies. Borrowed from [12] with information from [2] and [9].

Our protagonists

Initial positions of the players:

1. *Empaque Los Reyes S.A. de C.V.* Located at $v_1(0) = (-102.5018, 19.6994)$. (Red marker in figure 3.)
2. *Avocados Esquivel S. de R.L.* Located at $v_2(0) = (-102.4214, 19.5266)$. (Blue marker in figure 3.)
3. *Avoproduce México, S. de P.R. de R.L. de C.V.* Located at $v_3(0) = (-101.9380, 19.4136)$. (Orange marker in figure 3.)

This proposal is directed to
the sixth phase referred to in table 1: transportation to packing facilities.

Game rules I

Definition 1

Let S be a finite set, whose members are

$$(0, v)\text{–Shock due to accident or robbery while going to location } v,$$
$$(1, v)\text{–Client of the first packing company at location } v,$$
$$(2, v)\text{–Client of the second packing company at location } v,$$
$$(3, v)\text{–Client of the third packing company at location } v,$$

where $v \in [-103.216667, -101.783333] \times [18.75, 20.1]$, *i.e.*, v is a point in the rectangle referred to in figure 3.

Remark 1

To ensure S is a finite set, at each time, we allow v to take on only the coordinates of the available packing facilities placed by the central players.

Game rules II

Only one

new packing house by each company.

The status of the n-th orchard at time $t = 0, 1, \dots$

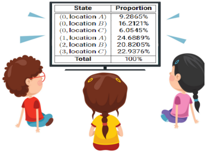
is a random variable $X_n^{35000}(t) : \Omega \to S$ defined on the probability space $(\Omega, \mathcal{F}, \mathbb{P})$ for $n = 1, \dots, 35000$.

Our central agents will (try to)

control the process $\left(X_n^{35000}(t) : t = 0, 1, \dots\right)$ for $n = 1, \dots, 35000$. The agents will choose their actions $u_1(t), u_2(t), u_3(t)$ at each time $t = 0, 1, \dots$, from given Borel sets U_1, U_2, U_3, respectively. For us,

$$U_k = \{[-103.216667, -101.783333] \times [18.75, 20.1]\} \cup \{\text{¯\\_(ツ)_/¯}\} \text{ for } k = 1, 2, 3.$$

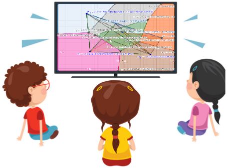
Evolution of the system



(a) Central agents observe market shares $\vec{m}(t) \in \mathbb{P}(S)$. (img: vectorstock.com.)

(b) Each agent chooses $u_k = u_k(t) \in U_k$. Image borrowed from here.

(c) Agents earn rewards $c_k(\vec{m}, u_1, u_2, u_3)$. Image borrowed from here.



(d) System evolves to a new state $\vec{m}' = \vec{M}^{35000}(t+1) \in B$. (img: vectorstock.com.)

The ultimate goal

of the k-th central agent is to maximize

$$J_k^{35000}\left(\pi^{35000}, \vec{m}\right) :=$$

$$\liminf_{T\to\infty} \frac{1}{T} \mathbb{E}_{\vec{m}}^{\pi_1^{35000},\pi_2^{35000},\pi_3^{35000}} \left[\sum_{t=0}^{T-1} c_k\left(\vec{M}^{35000}(t), u_1(t), u_2(t), u_3(t)\right)\right],$$

where π_ι^{35000} stands for the sequence of actions taken along time by the ι-th player, for $\iota = 1, 2, 3$; and $\mathbb{E}_{\vec{m}}^{\pi_1^{35000},\pi_2^{35000},\pi_3^{35000}}[\cdot]$ is the conditional expectation of $[\cdot]$ given that the central players use the sequence of actions $\left(\pi_1^{35000}, \pi_2^{35000}, \pi_3^{35000}\right)$, and the distribution of the market share is $\vec{m}$.

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Hotelling-Cournot model without crime

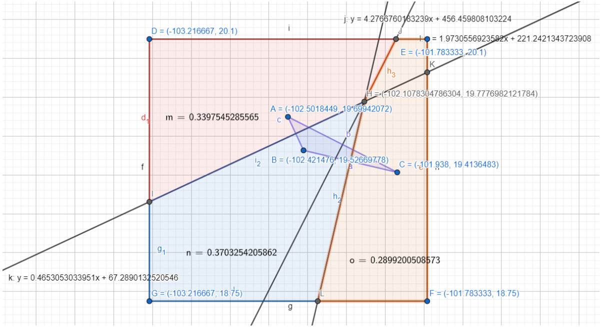

Figure 5: Initial distribution of the market shares *without* considering the pernicious action of crime.

A measure of “bad luck” I

The probability of transition of $X_n^{35000}(\cdot)$ for $n = 1, 2, ..., 35000$ is

$$\mathbb{P}\left(X_n^{35000}(t+1) = j | X_n^{35000}(t) = i, u_1(t) = u_1, u_2(t) = u_2, u_3(t) = u_3\right)$$
$$= \int_{\mathbb{R}} \mathbb{I}_j\left(F(i, u_1, u_2, u_3, \xi)\right) \rho(\xi) \mathrm{d}\xi.$$

To estimate the density of the random variable ξ,

we use the information from table 2. The probability that a citizen from Michoacán taken at random suffers at least an extortion, a kidnapping, a car theft, or other sorts of robbery during a year is of $\frac{5050+1982+1775+1801}{100{,}000} = 0.10608.$

A measure of “bad luck” II

Definition 2

Let N be the random variable that counts the number of felonies suffered by a transporter during the year. If further, we assume that N follows Poisson's law, then we have that $\mathbb{P}(N \geq 1) = 0.10608$, which means that

$$\mathbb{P}(N = 0) = 0.89392.$$

We use definition 2 to obtain the intensity rate *per annum*

of $\lambda = 0.112138993$ for the felonies suffered by transporters in Michoacán. This number can be used to compute the probability that a transporter gets hijacked during a t-hour period with an Exponential approach: $1 - \exp(-\lambda t)$.

A measure of “bad luck” III

Example 3

We readily know that the longest a truck spends on the road is four hours. Then, the estimated probability that they suffer an assault is

$$1 - \exp\left(-0.112138993 \cdot \frac{4}{24 \times 365}\right) = 0.0000512037.$$

Theorem 4

Fix $(u_1, v_1) \in \mathcal{A}$, and let $(x, y) \in \mathcal{A}$. Since the time spent on the road to go from (u, v) to (x, y) is $\frac{4}{1.11157}\sqrt{(x-u)^2 + (y-v)^2}$, then the probability of a robbery on $\mathcal{A}$ is $\int_{\mathcal{A}} \int_0^{\frac{4}{1.11157}\sqrt{(x-u)^2+(u-v)^2}} 1 - \mathrm{e}^{-\lambda t} \mathrm{d}t \mathrm{d}\mathcal{A}$.

A measure of “bad luck” in the blue region

By virtue of theorem 4, the proportion of stolen goods in the blue region from figure 5 is:

$$\int_{18.75}^{19.2618}\int_{-103.217}^{\frac{y-456.4898}{4.2766}}\int_{0}^{\frac{4}{1.11157}\sqrt{(x+102.42)^2+(y-19.526)^2}} 1-\mathrm{e}^{-0.1121t}\mathrm{d}t\mathrm{d}x\mathrm{d}y$$

$$+\int_{19.2618}^{19.7777}\int_{\frac{y-67.2890}{0.4653}}^{\frac{y-456.4898}{4.2766}}\int_{0}^{\frac{4}{1.11157}\sqrt{(x+102.42)^2+(y-19.526)^2}} 1-\mathrm{e}^{-0.1121t}\mathrm{d}t\mathrm{d}x\mathrm{d}y$$

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$$+\int^{19.7777}\int^{\frac{y-456.4898}{4.2766}}\int^{\frac{4}{1.11157}\sqrt{(\ldots 2)^2+(y-19.526)^2}} 1-\mathrm{e}^{-0.1121t}\,\mathrm{d}t\,\mathrm{d}x\,\mathrm{d}y$$

0.1621212

A measure of “bad luck” in the red region

By virtue of theorem 4, the proportion of stolen goods in the red region from figure 5 is:

$$\int_{19.2618}^{19.7769}\int_{-103.217}^{\frac{y-67.2890}{0.4653}}\int_{0}^{\frac{4}{1.11157}\sqrt{(x+102.5018)^2+(y-19.6994)^2}} 1-\mathrm{e}^{-0.1121t}\mathrm{d}t\mathrm{d}x\mathrm{d}y$$

$$+\int_{19.7777}^{20.1}\int_{-103.2467}^{\frac{y-67.2890}{0.4653}}\int_{0}^{\frac{4}{1.11157}\sqrt{(x+102.5018)^2+(y-19.6994)^2}} 1-\mathrm{e}^{-0.1121t}\mathrm{d}t\mathrm{d}x\mathrm{d}y$$

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A measure of "bad luck" in the red region

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$$+\int_{19.7\ldots}^{20.1}\int^{\frac{y-67.2890}{0.4653}}\int^{\frac{4}{1.11157}\sqrt{(x+1\ldots)^2+(y-19.6994)^2}} \ldots e^{-0.1121t}\,dt\,dx\,dy$$

0.092865

A measure of "bad luck" in the orange region

By virtue of theorem 4, the proportion of stolen goods in the orange region from figure 5 is:

$$\int_{18.75}^{19.7777}\int_{\frac{y-456.4898}{4.2766}}^{-101.7833}\int_{0}^{\frac{4}{1.11157}\sqrt{(x+101.938)^2+(y-19.4143)^2}} 1-\mathrm{e}^{-0.1121t}\mathrm{d}t\mathrm{d}x\mathrm{d}y$$

$$+\int_{19.777698}^{20.1}\int_{\frac{y-221.24213}{1.9730556}}^{-101.7833}\int_{0}^{\frac{4}{1.11157}\sqrt{(x+101.938)^2+(y-19.4136^2}} 1-\mathrm{e}^{-0.1121t}\mathrm{d}t\mathrm{d}x\mathrm{d}y$$

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A measure of “bad luck” in the orange region

By virtue of theorem 4, the proportion of stolen goods in the orange region from figure 5 is:

$$\int_{18.75}^{19.7777} \int_{\frac{y-456.4898}{4.2766}}^{-101.7833} \int_{0}^{\frac{4}{1.11157}\sqrt{(x+101.938)^2+(y-19.4143)^2}} 1 - \mathrm{e}^{-0.1121t} \mathrm{d}t\mathrm{d}x\mathrm{d}y$$

$$+ \int_{19\ldots}^{20.1} \int^{-101.7833} \int^{\frac{4}{1.11157}\sqrt{(\ldots 8)^2+(y-19.4136^2}} \ldots \mathrm{e}^{-0.1121t} \mathrm{d}t\mathrm{d}x\mathrm{d}y$$

0.0605446

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Setting the board

State	Proportion
$(0,$ location $A)$	9.2865%
$(0,$ location $B)$	16.2121%
$(0,$ location $C)$	6.0545%
$(1,$ location $A)$	24.6889%
$(2,$ location $B)$	20.8205%
$(3,$ location $C)$	22.9376%
Total	100%

Table 3: Initial distribution of the orchards among the packing facilities and the criminals.

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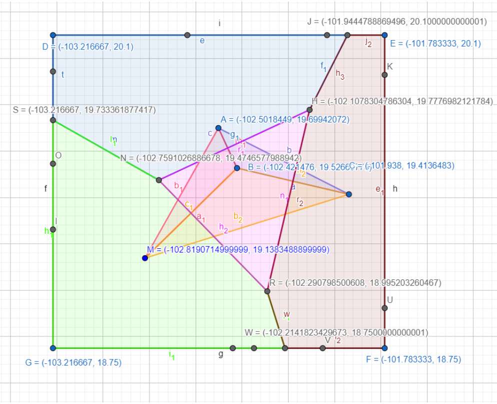
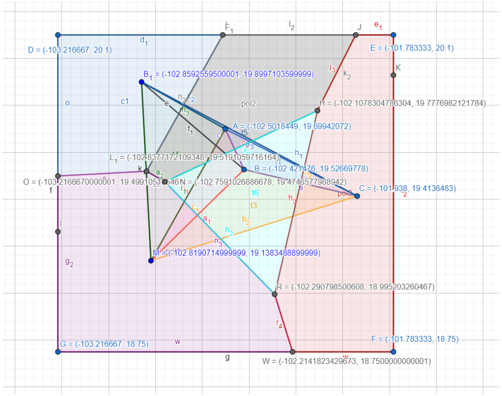
Sequential Hotelling-Cournot model (no crime)



Distribution of the market shares *without* considering the pernicious action of crime after the action of player B.

Sequential Hotelling-Cournot model (no crime)



Distribution of the market shares *without* considering the pernicious action of crime after the action of players B and A.

Sequential Hotelling-Cournot model (no crime)

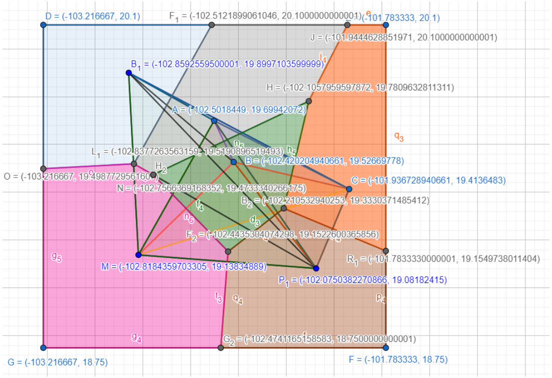


Figure 6: Distribution of the market shares *without* considering the pernicious action of crime after the action of players B, A and C.

Settling the board

Player	Initial market share	Market share at equilibrium
Empaque Los Reyes	24.6888%	27.9112%
Avocados Esquivel	20.8205%	33.0206%
Avopoduce México	22.9376%	28.1823%
Pirates	31.5531%	10.8859%
TOTAL	100%	100%

Comparison of the market shares on table 3, and after the players have exhausted their optimal actions.

A rehabilitated toll road I

From	To	Distance	ADT	Trucks
Pátzcuaro	Huerta Mi Bonita	13.5km	7418	20.9%
Huerta Mi Bonita	Zirahuén	5.5km	6688	18.8%
Zirahuén	Santa Clara del Cobre	12km	11699	24.7%
Santa Clara del Cobre	Jujúcato	7.4km	10322	19.9%
Jujúcato	Ziracuaretiro 1	8.5km	10430	22.9%
Ziracuaretiro 1	Ziracuaretiro 2	4.7km	10220	23.3%
Ziracuaretiro 2	Lazáro Cárdenas	3.1km	18683	20.1%
Lazáro Cárdenas	Uruapan	12.1km	20360	20%

Table 4: Sections of the highway from Pátzcuaro to Uruapan. Source: [7].

A rehabilitated toll road II

Unfortunately, even on these modernized roads, criminals have found ways to affect transporters.

The ADT can help us price hedging instruments against these phenomena in the fashion of [8].

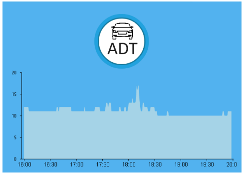
Assumption 1

The highway manager is interested in offering insurance to avocado transporters in case they suffer theft of goods in transit on the highway. To transfer the risk, they would buy coverage from a third party in exchange for a (fair) premium we propose to cover its risk using a correlated variable the ADT.

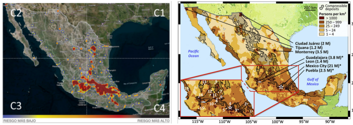
This proposal is directed to

the eighth phase referred to in table 1: transportation to export ports or domestic transportation.

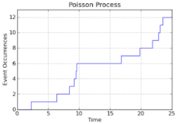
An attainable earnout



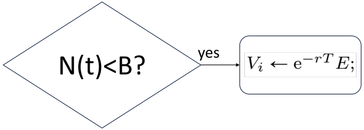
(a) Strict control of ADT. Image derived from here.



(b) The cargo theft and population density maps seem to sustain that a highway with low ADT is more prone to cargo theft. Images borrowed from [17] and [4], respectively.



(c) Poisson simulation with $\lambda = \mathbb{E}(ADT)$. Image borrowed from here.



(d) Binary-like method.

Valuation algorithm

October	0.89415	November	0.96435
December	1.09077	January	0.94472
February	0.86806	March	0.95401
April	1.14642	May	1.00693
Jun	0.97059	July	1.16154
August	1.05416	September	0.94429

Table 5: The seasonal coefficients for the 2023-2024. Source: [8].

$$r = 11.48\%$$
$$B = 20360 \times 20\% = 4072$$
$$E = 10^6$$
$$\lambda = 2546.82$$

Algorithm 2: Computation of a 95%-confidence interval for the fair price of the down-and-out option *with single arrival* of American type

Data: Number of simulations to perform M; time horizon T; barrier to cross/reach at least one time B; number of evaluations of the barrier L; monthly daily average volume at the initial time S_0; strike price E; discount rate r; Poisson intensity λ; vector of seasonal coefficients R.

Result: 95%-confidence interval for the instrument's value at time $t = 0$.

Compute the step size $\Delta t \leftarrow \frac{T}{L}$;
for $i \leftarrow 1$ **to** M **do**
  $I \leftarrow 0$;
  $j \leftarrow 1$;
  for $I < 1$ **to** $j \leqslant 1$ **do**
    Compute a realization of the random variable $\xi_j \sim \text{Poisson}(\lambda \cdot j \cdot \Delta t)$;
    $S_{j+1} \leftarrow \xi_j$;
    $\bar{S}_{j+1} \leftarrow L \cdot \frac{R_j}{\sum_{k=1}^{L} R_k} \cdot S_{j+1}$;
    if $\bar{S}_{j+1} \leqslant B$ **then**
      $I \leftarrow I + 1$;
    end
  end
  $j \leftarrow j + 1$
  if $I \geqslant 1$ **then**
    $V_i \leftarrow e^{-rT} E$;
  else
    $V_i \leftarrow 0$;
  end
end
$a_M \leftarrow \frac{1}{M} \sum_{i=1}^{M} V_i$;
$b_M^2 \leftarrow \frac{1}{M-1} \sum_{i=1}^{M} (V_i - a_M)^2$;
return $\left[a_M - 1.96 \frac{b_M}{\sqrt{M}}; a_M + 1.96 \frac{b_M}{\sqrt{M}}\right]$;

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The result

Example 5

We simulate 100,000 times on a one-year horizon and obtain a fair price of 117,693.70 Mexican peso for the instrument, which lies in the 95%-confidence interval $[117691.4, 117969.01]$. Note that our method gives the probability of exercise of this *earnout*. Indeed, taking $r = 0$ and $E = 1$ in our algorithm yields a probability of exercise of 13.39% (cf. [8] for some more details).

The rehabilitated toll road from Pátzcuaro to Uruapan. Source: [18].

Conclusions

Six conclusions I

We present two proposals
oriented to mitigate the risk of suffering losses due to the effect of crime in the Mexican state of Michoacán.

The first is a method to maximize the market share of the owners
of packing houses in the state. We assume that these facilities are located off the existing toll roads. As a by-product of our results, we have shown a way to estimate the probability that the transporters suffer a criminal action on their way toward the packing facilities.

The second proposal is a method to finance an insurance schema
by means of an instrument priced with the aid of the theory of contingent claims. It is oriented to the concessionaires in charge of the management of the highways in the state, and similar companies.

Six conclusions II

Our research is restricted

by the limitations of the two-dimensional view of the geography displayed in figure 3, as it does not consider any geographic accidents, such as rivers, elevations, or depressions. See figure 8, and compare it to figure 6. The difference is notorious.

Figure 8: Actual location of the cities that conform the region DOL_1F_1 in figure 6. Prepared with information from [20].

Six conclusions III

For the sake of illustration,
we have assumed that the distribution of the orchards in the land is uniform, but this hypothesis is not accurate. In the same thread of thought, we have willingly reduced the number of packing companies to only three.

From a theoretical point of view,
an advantage of the examples we presented is that they illustrate a realistic application of our methods.

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  How a priest in Mexico resists the CJNG's incursions.
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Doubts and Suggestions

daniel.lopez@anahuac.mx

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Two proposals to transfer some risks related to the carrying of avocado loads

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José Daniel López-Barrientos[1] Ana Pamela Flores-Herrera[2]
Ernesto Fernández-Arias[1] Beatris Adriana Escobedo-Trujillo[3]

[1]Facultad de Ciencias Actuariales
Universidad Anáhuac México

[2]Facultad de Comunicación
Universidad Anáhuac México

[3]Facultad de Ingeniería
Universidad Veracruzana

Facultad de Ciencias Actuariales

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