Uncertainty in agriculture

new directions for stochastic optimisation

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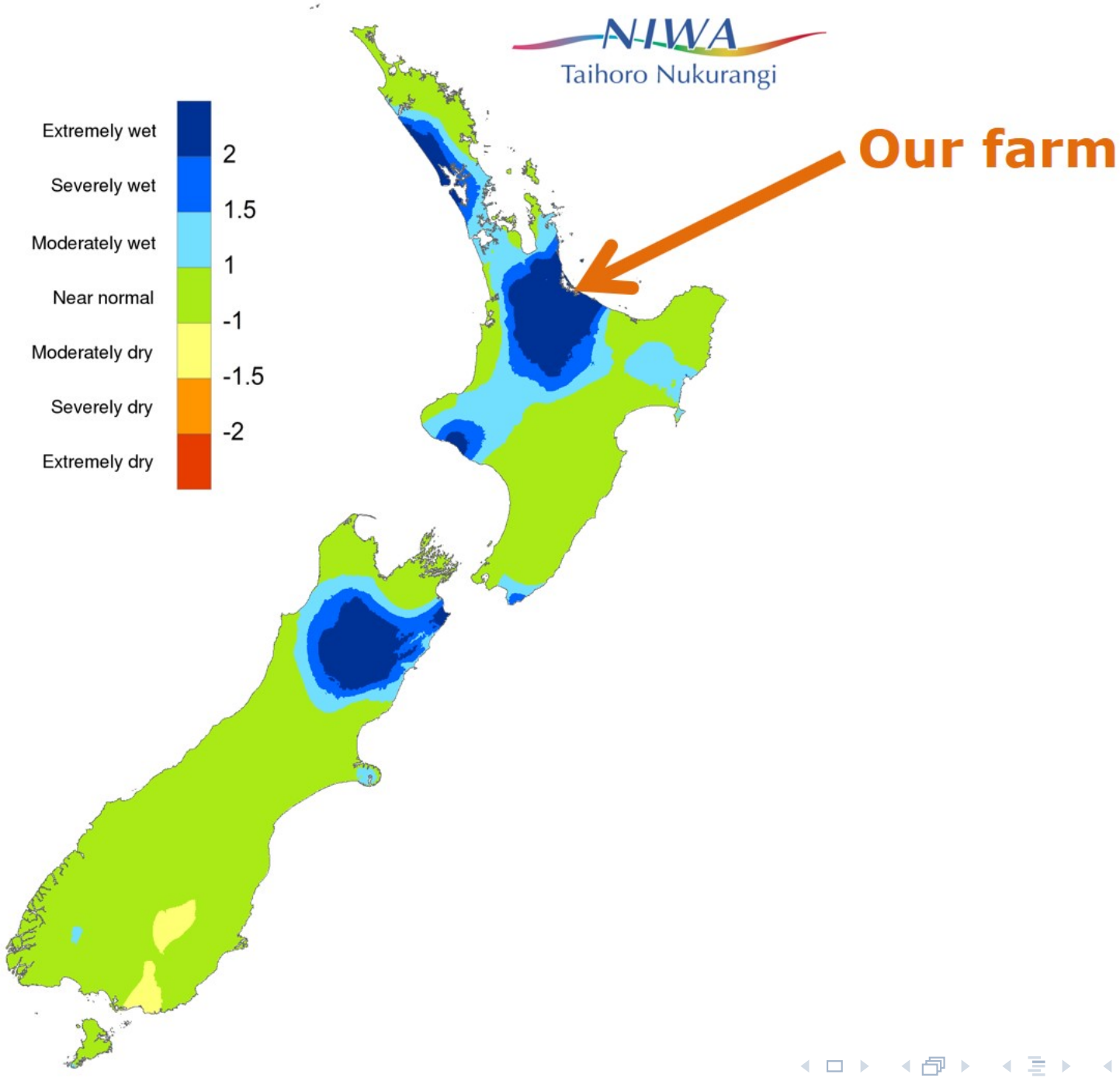
University of Auckland

June, 2018


In my opinion,
all palm oil
should be banned.

SPI Drought Index for 9am 27/08/2017 to 9am 26/09/2017



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- But, a wet year had left paddocks damaged.
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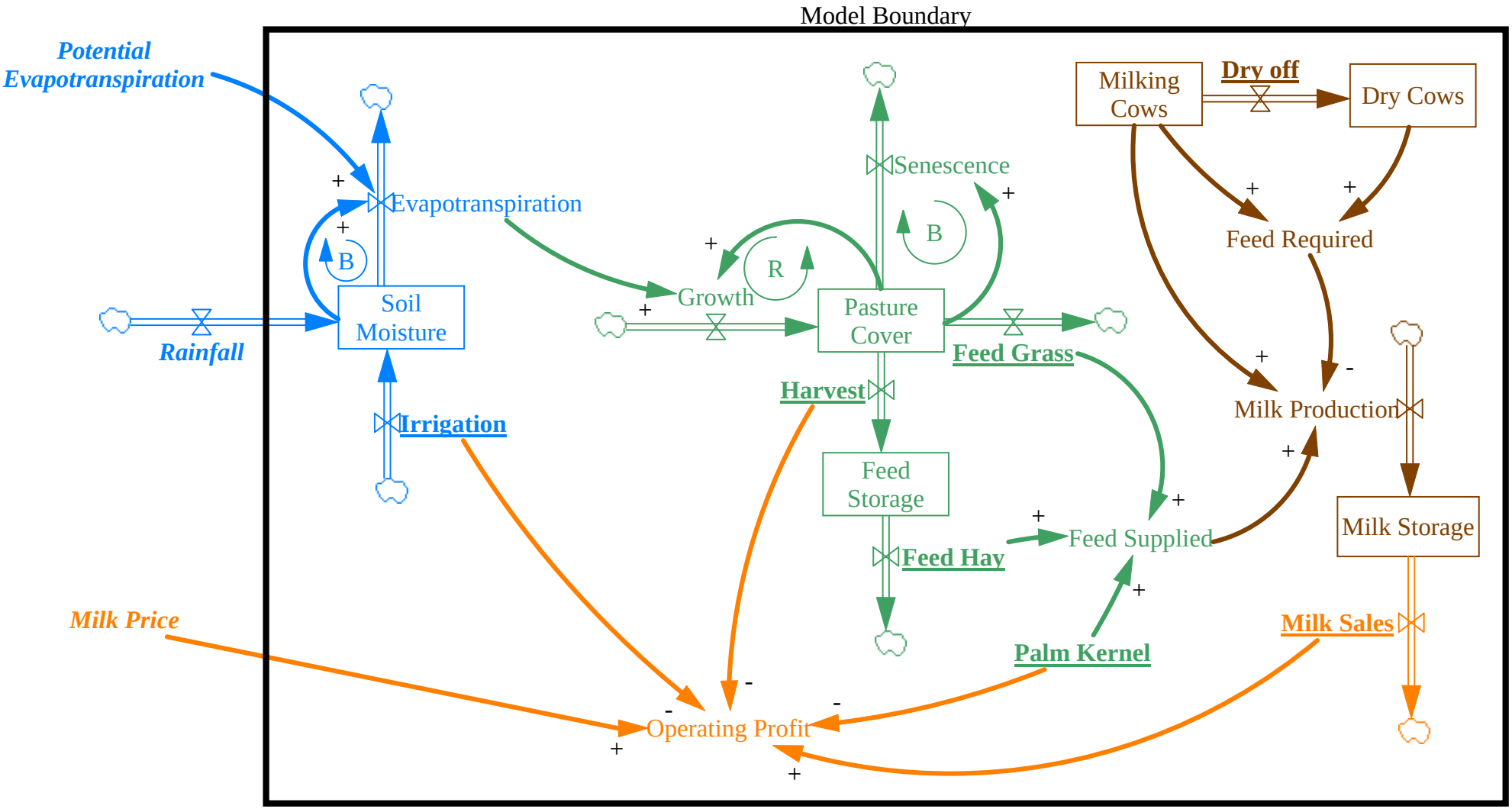
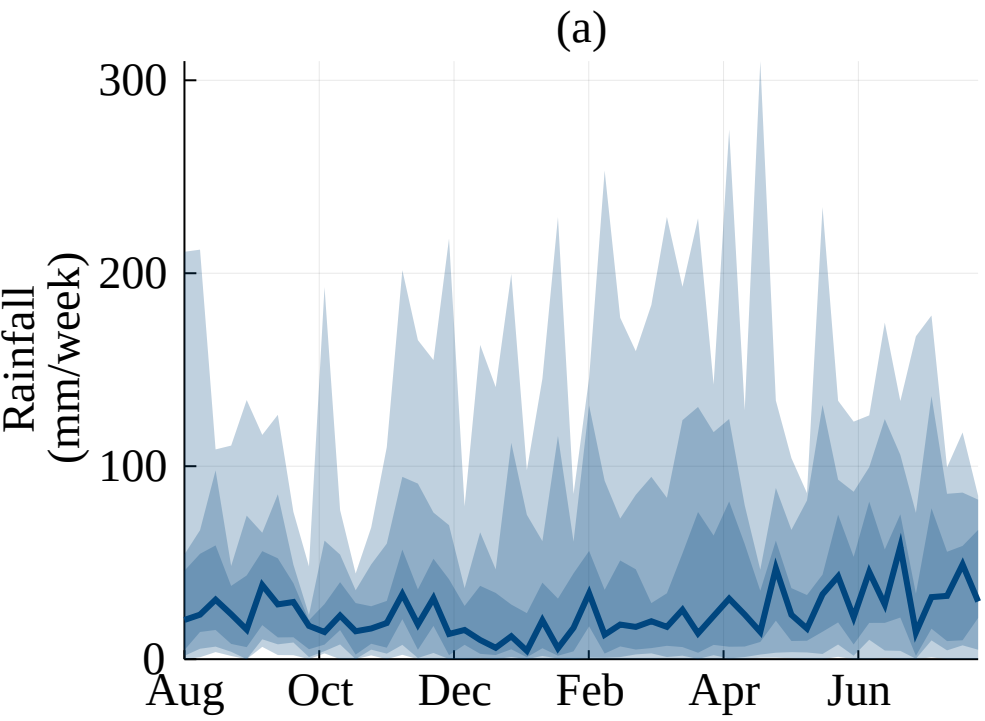
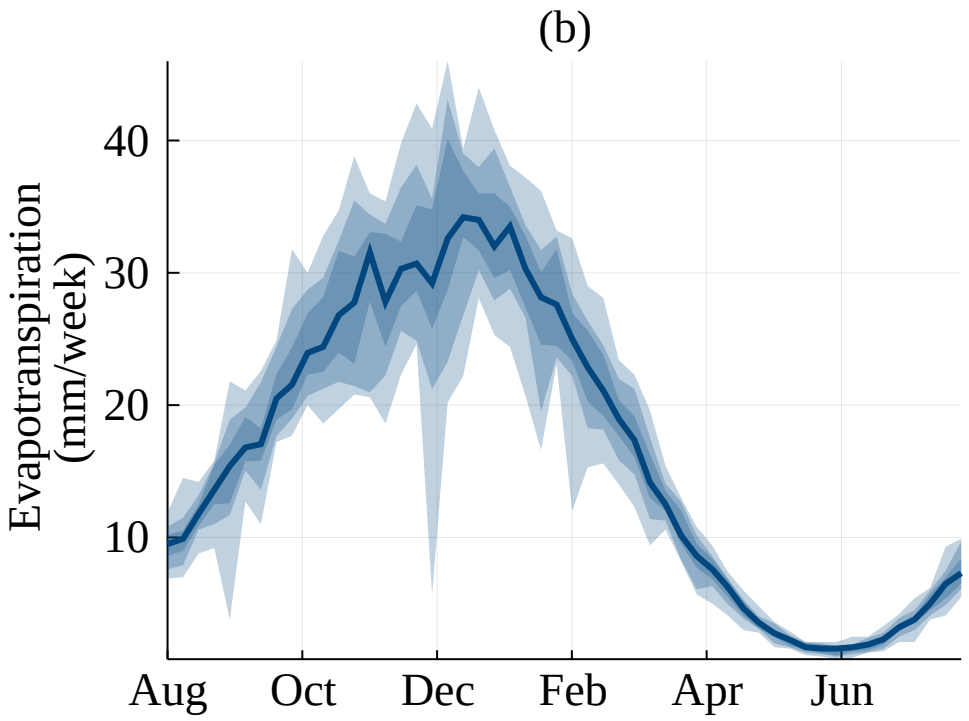
- Farm consultant's advice: "don't blink"

POWDER

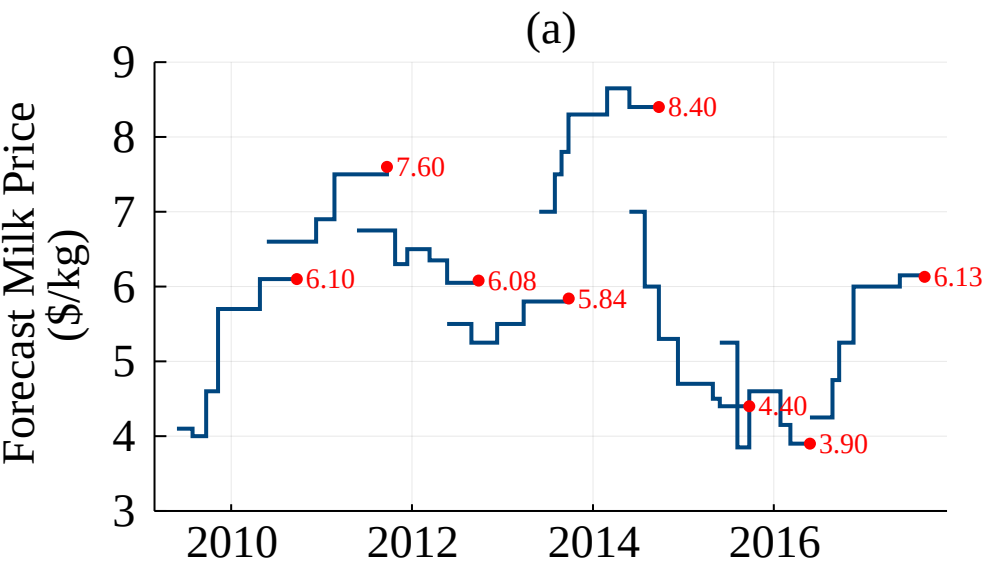

Model Boundary
Potential Evapotranspiration
Evapotranspiration
Soil Moisture
Rainfall
Irrigation
B
Growth
R
Senescence
B
Pasture Cover
Harvest
Feed Grass
Feed Storage
Feed Hay
Feed Supplied
Palm Kernel
Milking Cows
Dry off
Dry Cows
Feed Required
Milk Production
Milk Storage
Milk Sales
Milk Price
Operating Profit

POWDER


(a)
Rainfall (mm/week)
300
200
100
0
Aug
Oct
Dec
Feb
Apr
Jun


(b)
Evapotranspiration (mm/week)
40
30
20
10
Aug
Oct
Dec
Feb
Apr
Jun

POWDER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Forecast Milk Price ($/kg)
9
8
7
6
5
4
3
2010
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2014
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3.90
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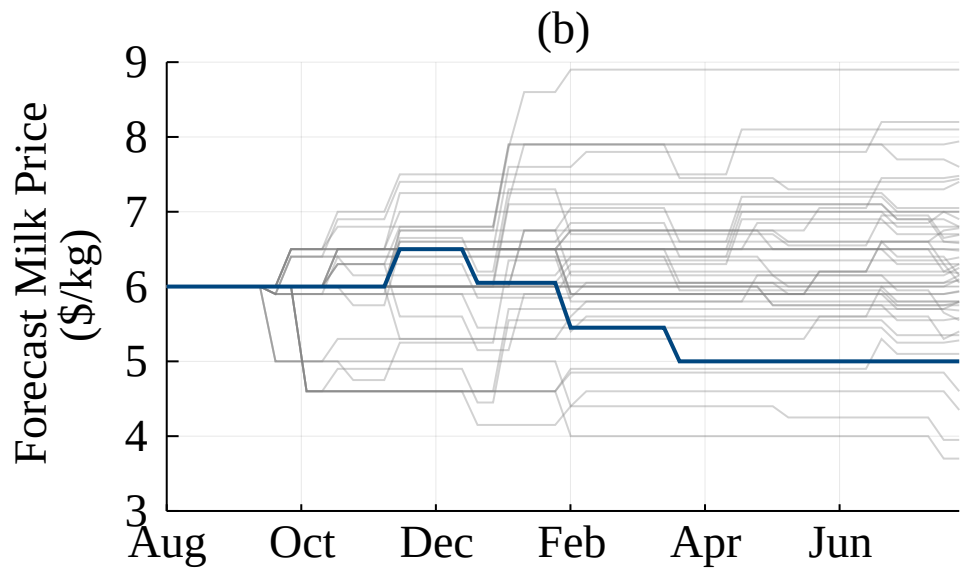
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Forecast Milk Price ($/kg)
9
8
7
6
5
4
3
Aug
Oct
Dec
Feb
Apr
Jun

POWDER

1. There are five state variables:
   - 1.1 the soil moisture;
   - 1.2 the pasture cover;
   - 1.3 the quantity of feed in storage;
   - 1.4 the number of cows milking; and
   - 1.5 the quantity of milk produced.

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2. There are three control variables:
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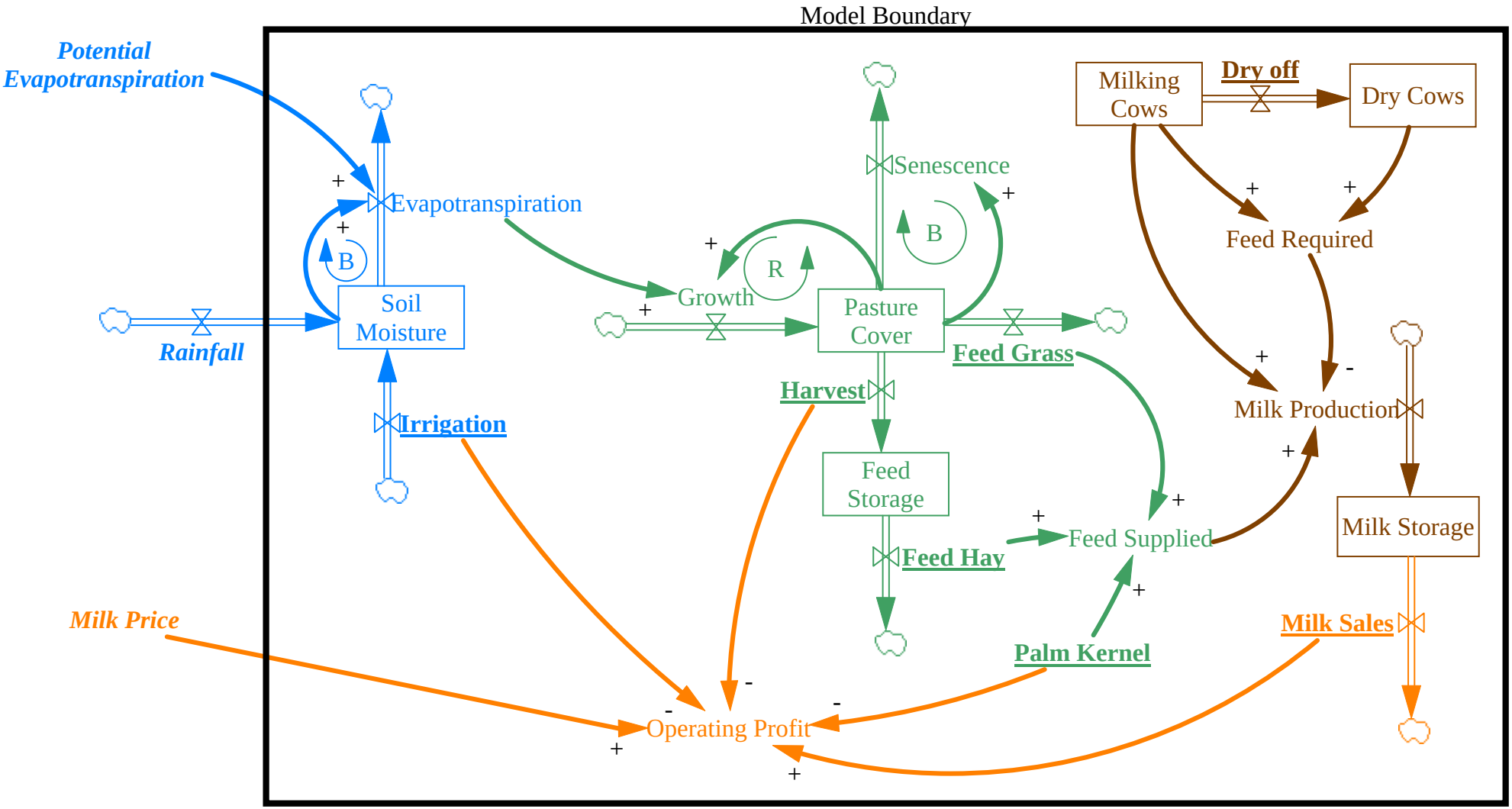
   - 2.2 the quantity of palm kernel to feed; and
   - 2.3 the number of cows to *dry-off*.
3. There are three random noise terms:
   - 3.1 the quantity of rainfall;
   - 3.2 the quantity of evapotranspiration; and
   - 3.3 a forecast milk price.

POWDER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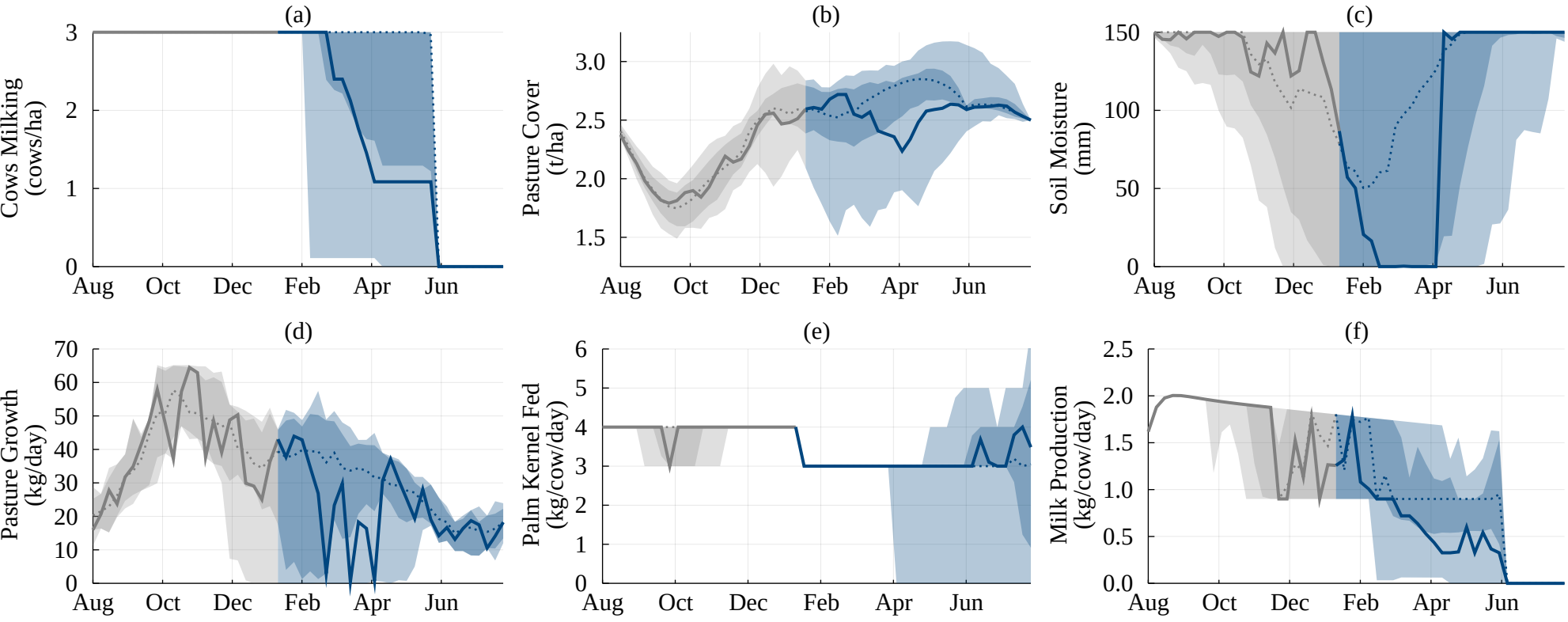
POWDER

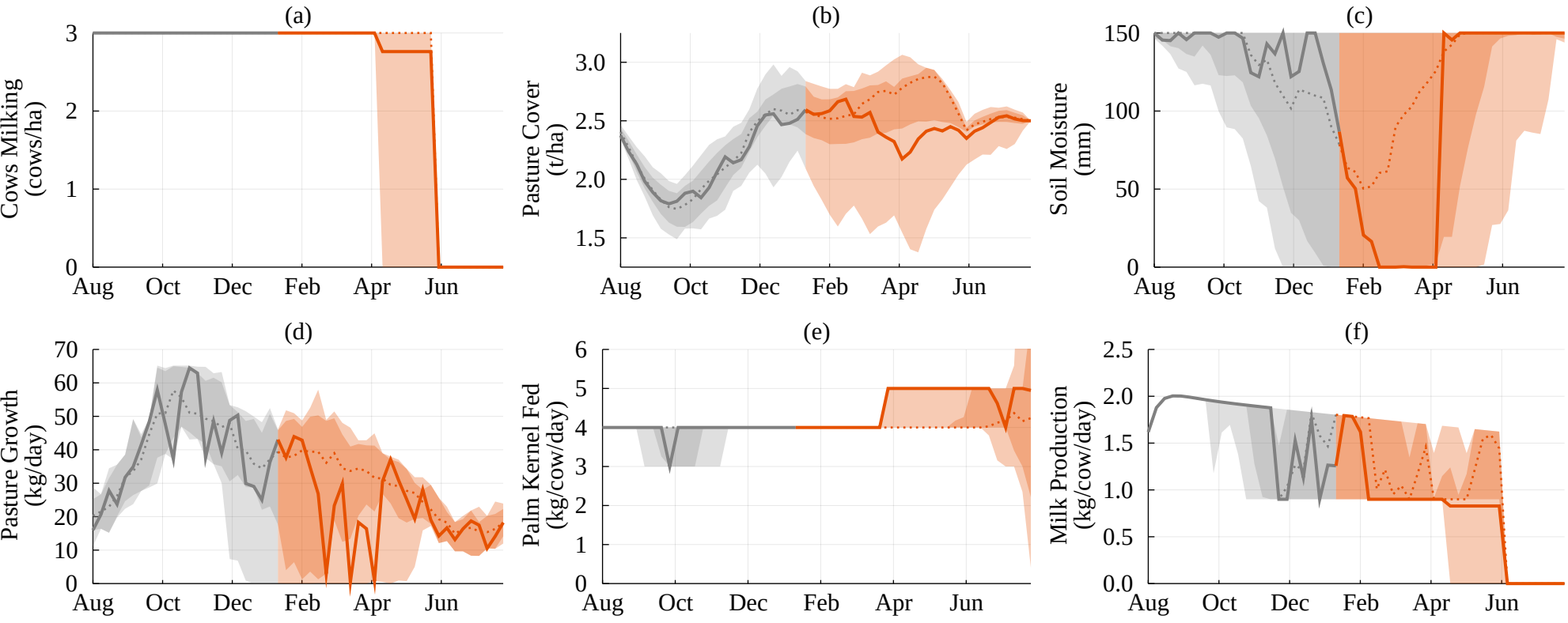
Now we're going to look at some results.

1. **BLUE** trajectories are **LOW** milk price years
2. **ORANGE** trajectories are **HIGH** milk price years

POWDER – Low Price Season



POWDER – High Price Season



Now lets add in contacting

1. Farmers get paid the *end-of-season* milk price;

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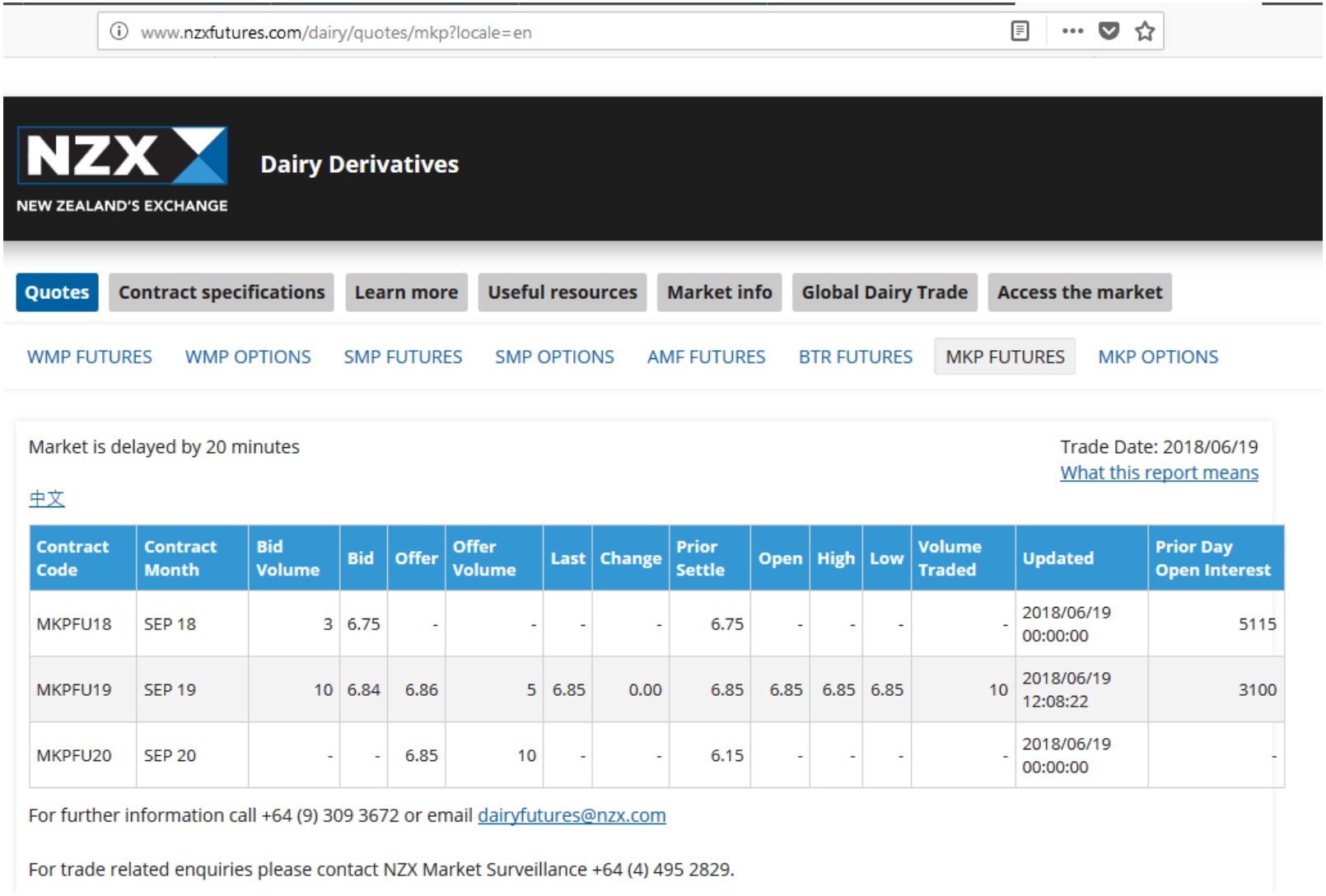
1. Farmers get paid the *end-of-season* milk price;
2. At any point in time, the *forward* milk price trades at the conditional expectation of the *end-of-season* milk price:

$$p_t^f = \mathbb{E}\left[p_{53} \mid p_t\right]$$

NZX Futures



www.nzxfutures.com/dairy/quotes/mkp?locale=en

NZX
NEW ZEALAND'S EXCHANGE

Dairy Derivatives

Quotes | Contract specifications | Learn more | Useful resources | Market info | Global Dairy Trade | Access the market

WMP FUTURES | WMP OPTIONS | SMP FUTURES | SMP OPTIONS | AMF FUTURES | BTR FUTURES | MKP FUTURES | MKP OPTIONS

Market is delayed by 20 minutes

Trade Date: 2018/06/19

What this report means

中文

Contract Code	Contract Month	Bid Volume	Bid	Offer	Offer Volume	Last	Change	Prior Settle	Open	High	Low	Volume Traded	Updated	Prior Day Open Interest
MKPFU18	SEP 18	3	6.75	-	-	-	-	6.75	-	-	-	-	2018/06/19 00:00:00	5115
MKPFU19	SEP 19	10	6.84	6.86	5	6.85	0.00	6.85	6.85	6.85	6.85	10	2018/06/19 12:08:22	3100
MKPFU20	SEP 20	-	-	6.85	10	-	-	6.15	-	-	-	-	2018/06/19 00:00:00	-

For further information call +64 (9) 309 3672 or email dairyfutures@nzx.com

For trade related enquiries please contact NZX Market Surveillance +64 (4) 495 2829.

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5115 contracts = 30 million kilograms = 2% of the underlying

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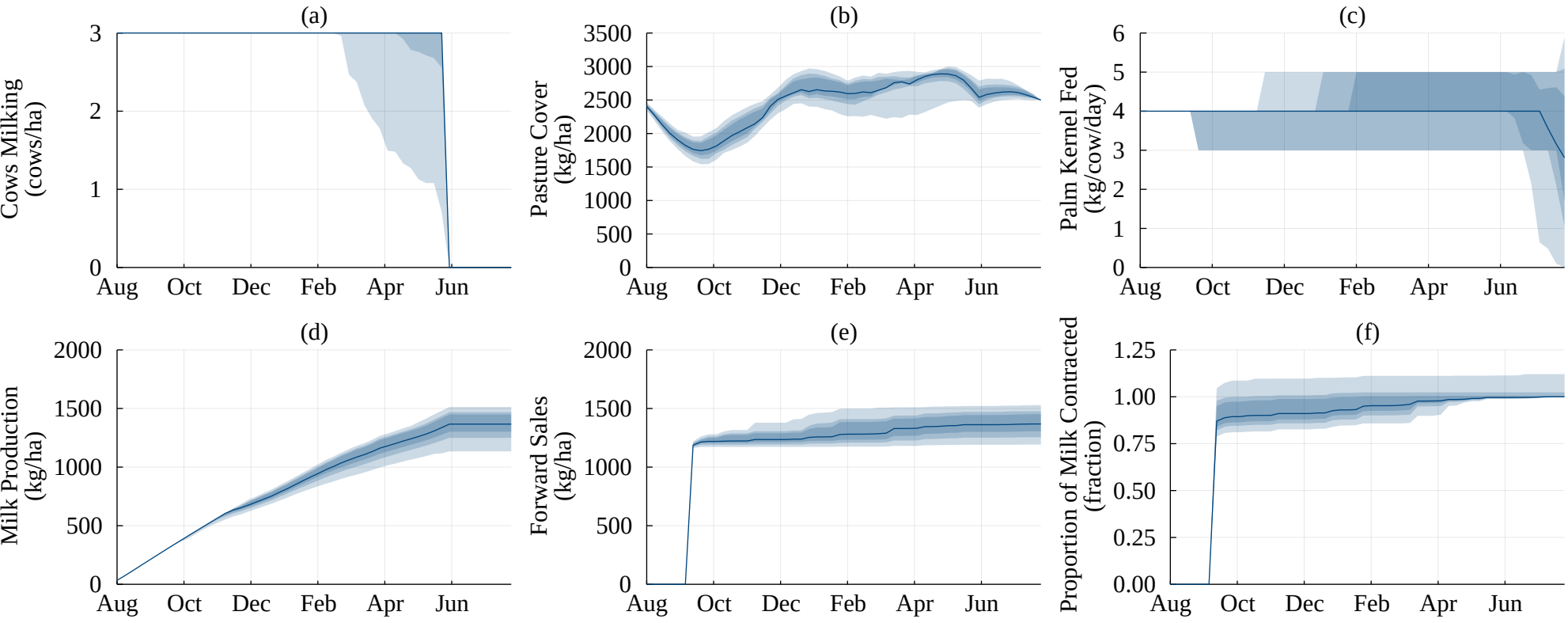
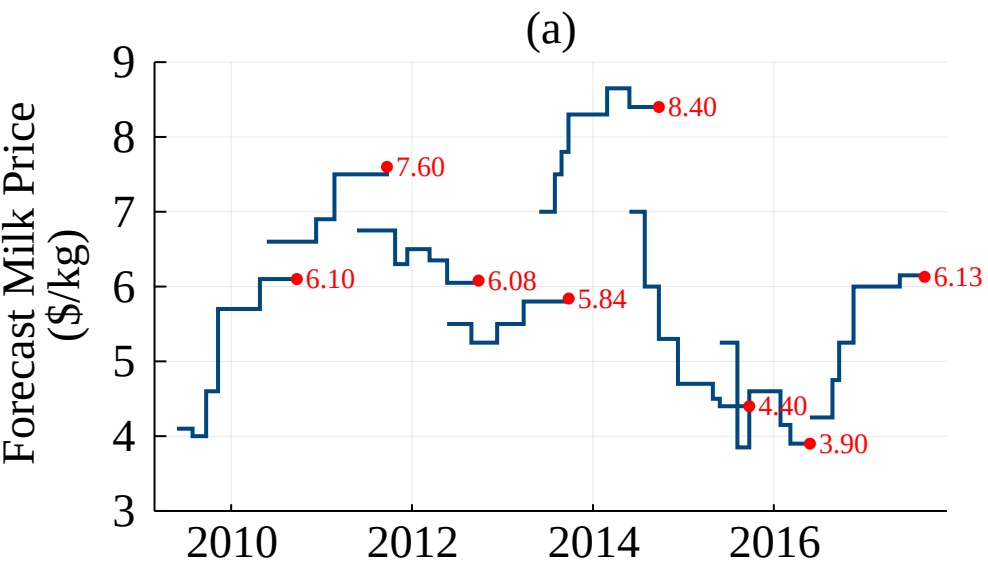

(a)
Cows Milking (cows/ha)
3
2
1
0
Aug
Oct
Dec
Feb
Apr
Jun
(b)
Pasture Cover (kg/ha)
3500
3000
2500
2000
1500
1000
500
0
Aug
Oct
Dec
Feb
Apr
Jun
(c)
Palm Kernel Fed (kg/cow/day)
6
5
4
3
2
1
0
Aug
Oct
Dec
Feb
Apr
Jun
(d)
Milk Production (kg/ha)
2000
1500
1000
500
0
Aug
Oct
Dec
Feb
Apr
Jun
(e)
Forward Sales (kg/ha)
2000
1500
1000
500
0
Aug
Oct
Dec
Feb
Apr
Jun
(f)
Proportion of Milk Contracted (fraction)
1.25
1.00
0.75
0.50
0.25
0.00
Aug
Oct
Dec
Feb
Apr
Jun

POWDER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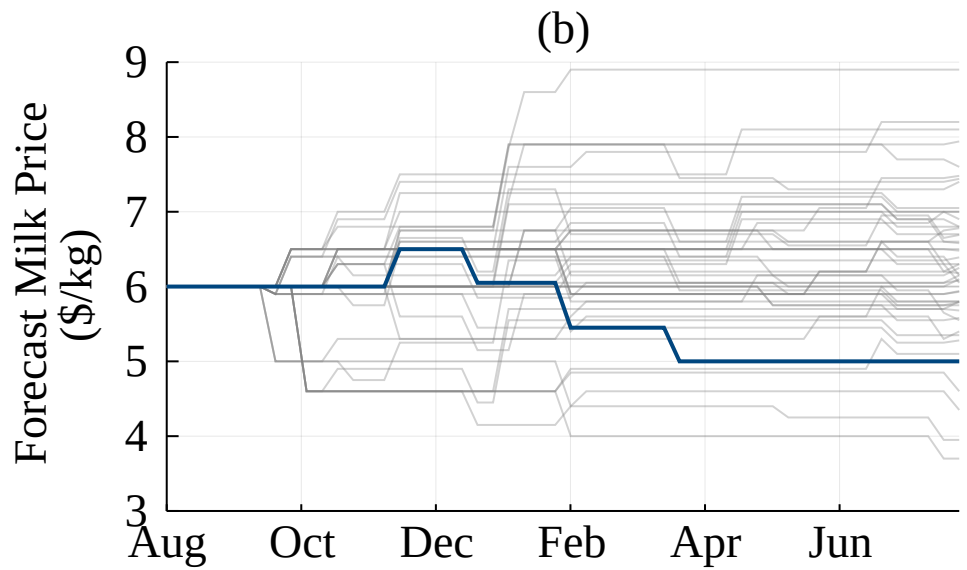
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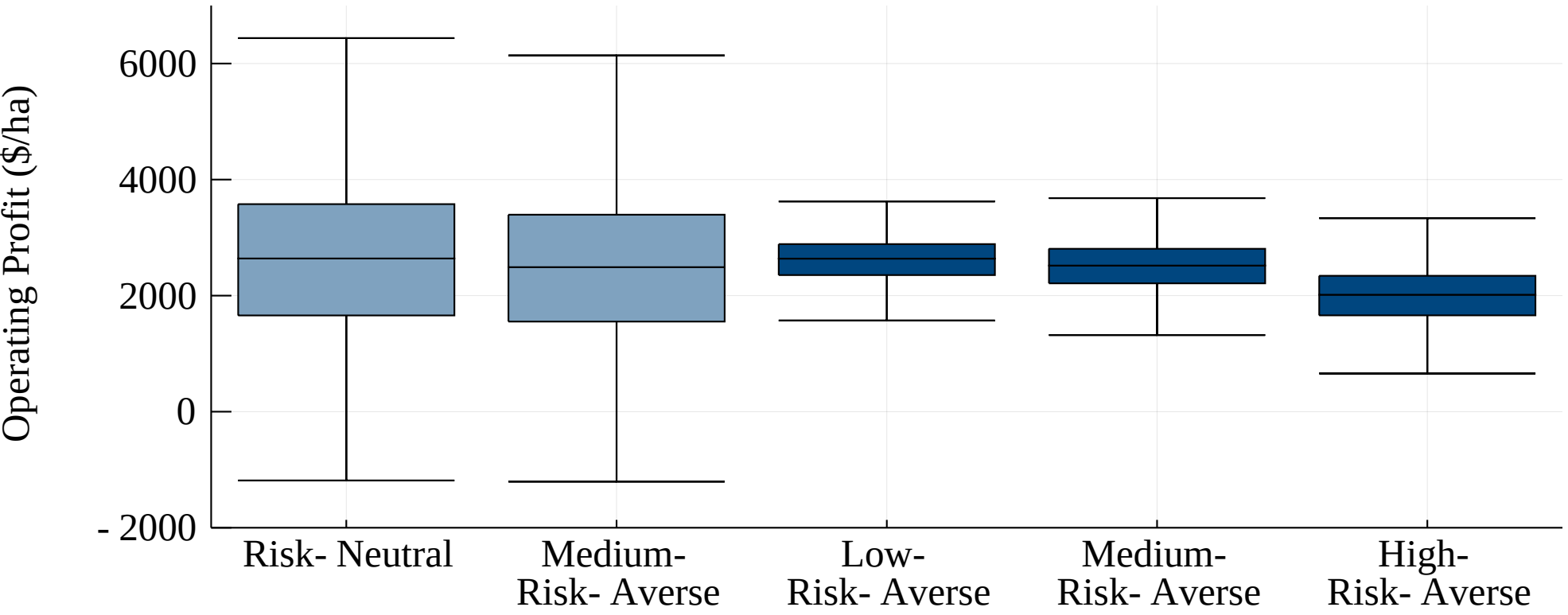
POWDER


Operating Profit ($/ha)
6000
4000
2000
0
- 2000
Risk- Neutral
Medium-
Risk- Averse
Low-
Risk- Averse
Medium-
Risk- Averse
High-
Risk- Averse

Opportunities in Agriculture

[There is] the need for considerable investment in adaptation and mitigation actions to prevent the impacts of climate change from slowing progress in eradicating global hunger and under-nutrition. [....] Building agricultural resilience, or 'climate-smart agriculture,' through improvements in technology and management systems is a key part of this.

Wheeler et al., (2013). Climate Change Impacts on Global Food Security. *Science*, 341:6145

Open Questions

THE UNIVERSITY OF AUCKLAND
Te Whare Wānanga o Tāmaki Makaurau
NEW ZEALAND

This talk is not just about cows.

Open Questions

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1. Swap cows for sheep

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1. Swap cows for sheep
2. Or grass for coffee

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1. Swap cows for sheep
2. Or grass for coffee
3. We can replicate this for many things with weather and price uncertainty.

Open Questions

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4. Weather is not stagewise-independent
   - Integrate Hidden Markov Models into SDDP
   - This feels a lot like price interpolation

Outline

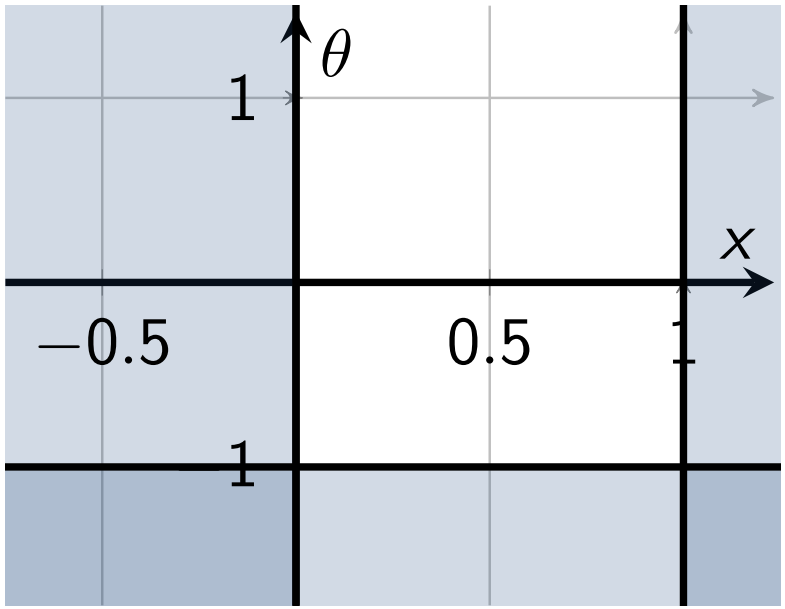
Degeneracy

$$
\begin{array}{lrrrrrrr}
\min & x & + & & & y_2 & & \\
\text{s.t.} & x & & & & & \leq & 1 \\
 & x & & & & & \geq & 0 \\
 & x & - & y_1 & & & = & 0 \\
 & & & y_1 & + & y_2 & \geq & 0 \\
 & & - & 3y_1 & + & y_2 & \geq & -2
\end{array}
$$

Degeneracy

$$
\begin{array}{lllrcrl}
\textbf{First Stage}: & \min & x & + & \theta & & \\
& \text{s.t.} & x & & & \leq & 1 \\
& & x & & & \geq & 0 \\
& & & & \theta & \geq & -1 \\
\textbf{Second Stage}: & \min & & & y_2 & & \\
& \text{s.t.} & y_1 & & & = & \hat{x} \quad [\lambda] \\
& & y_1 & + & y_2 & \geq & 0 \\
& & -3y_1 & + & y_2 & \geq & -2
\end{array}
$$

Degeneracy



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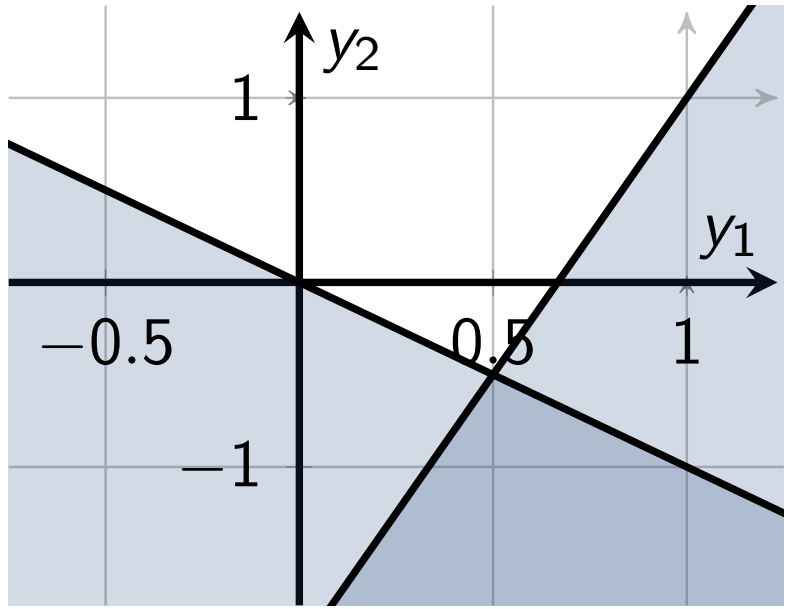
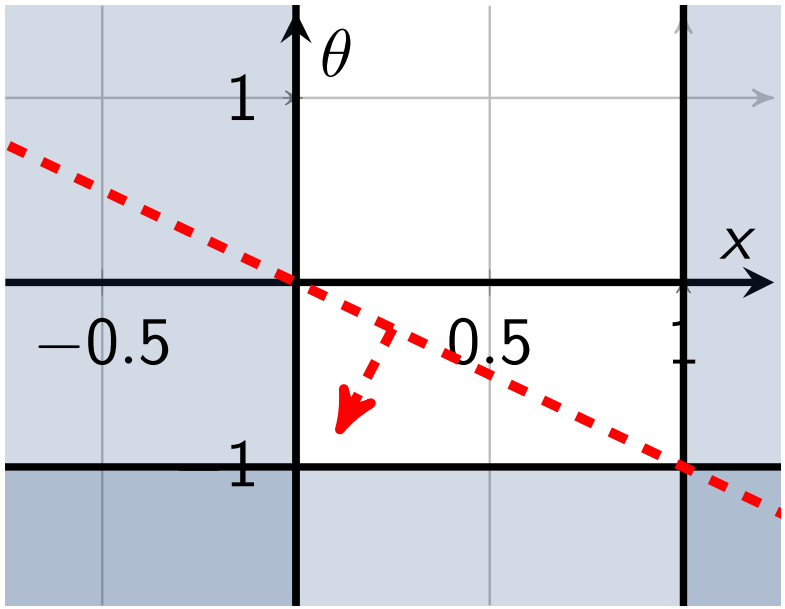


(b) Second Stage

Degeneracy



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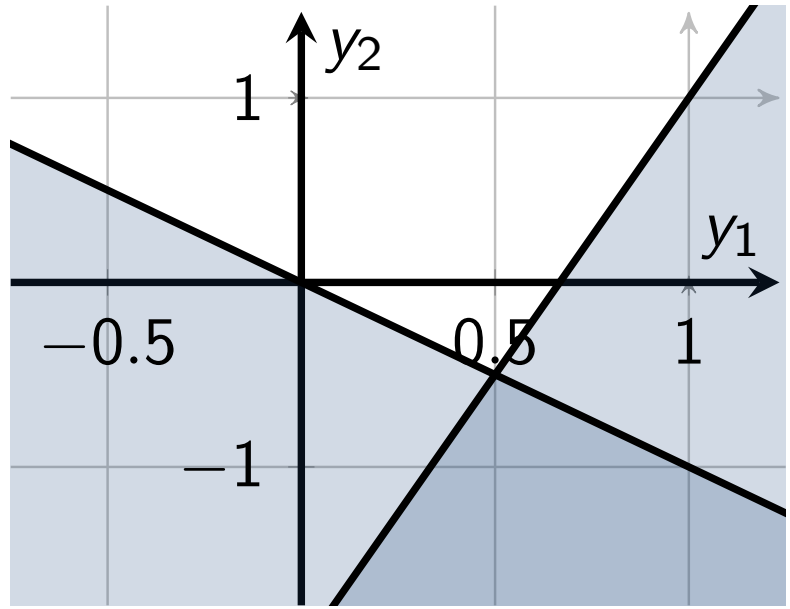

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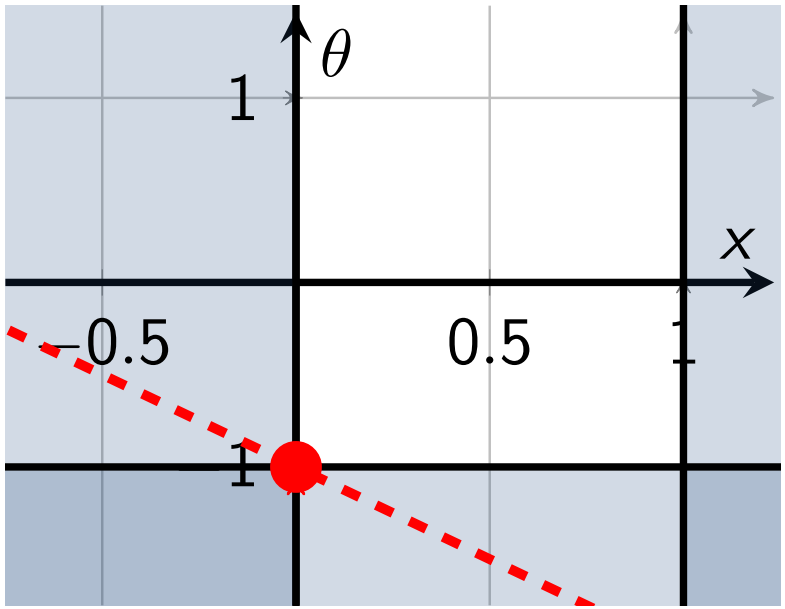

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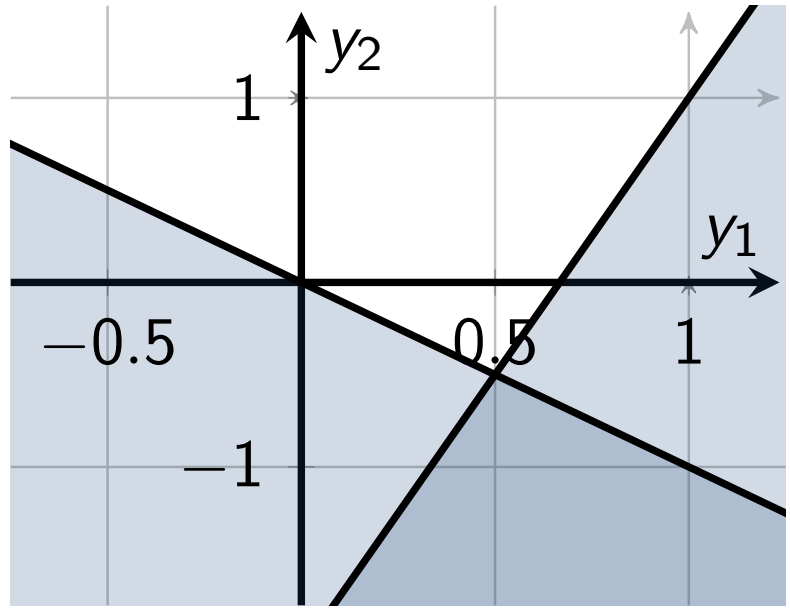

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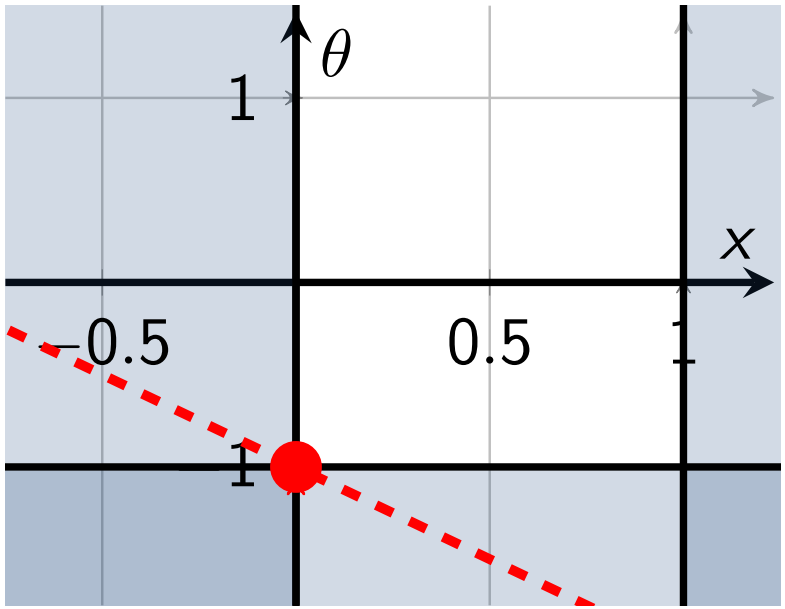

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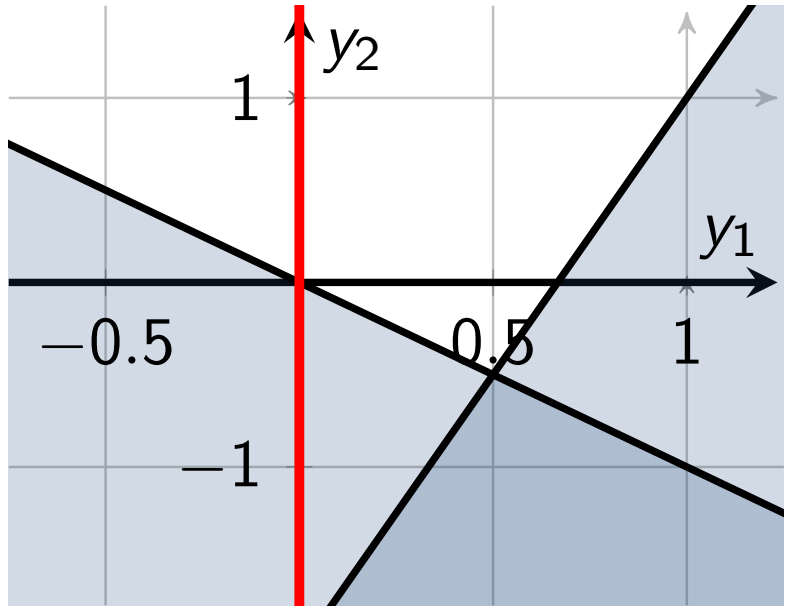

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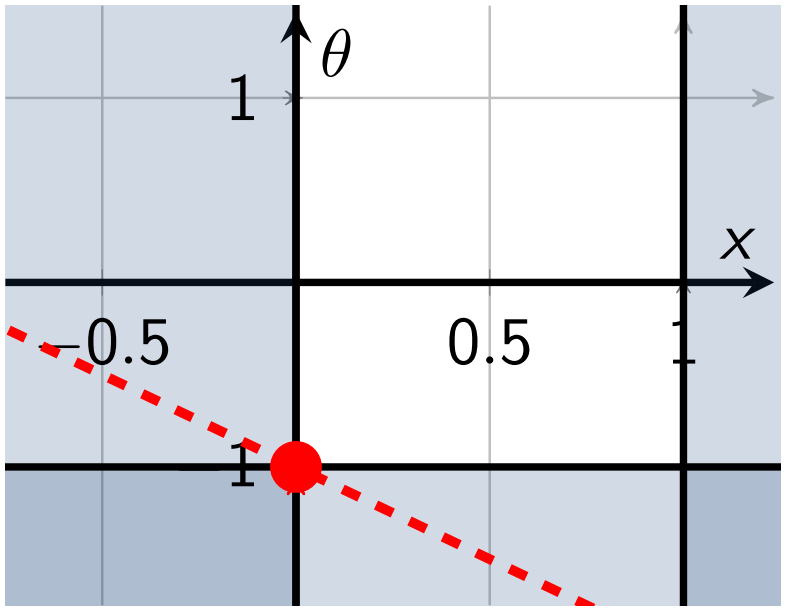

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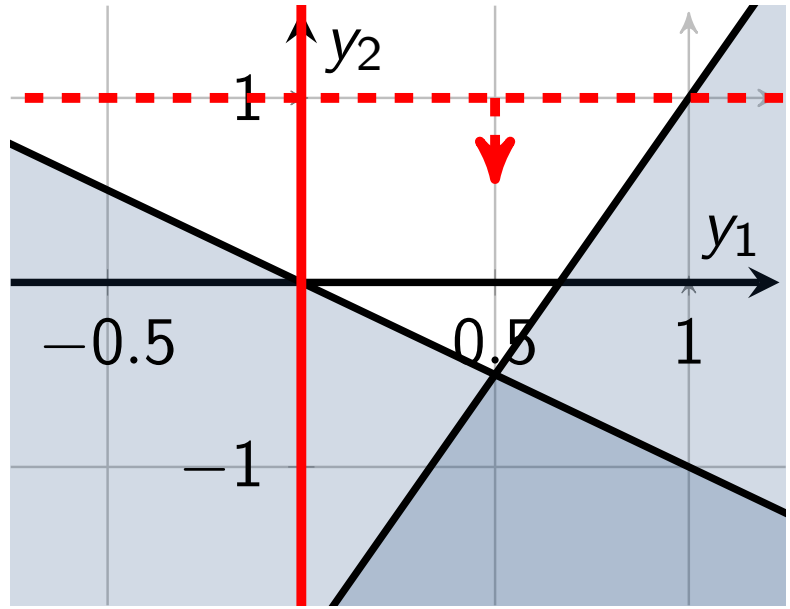

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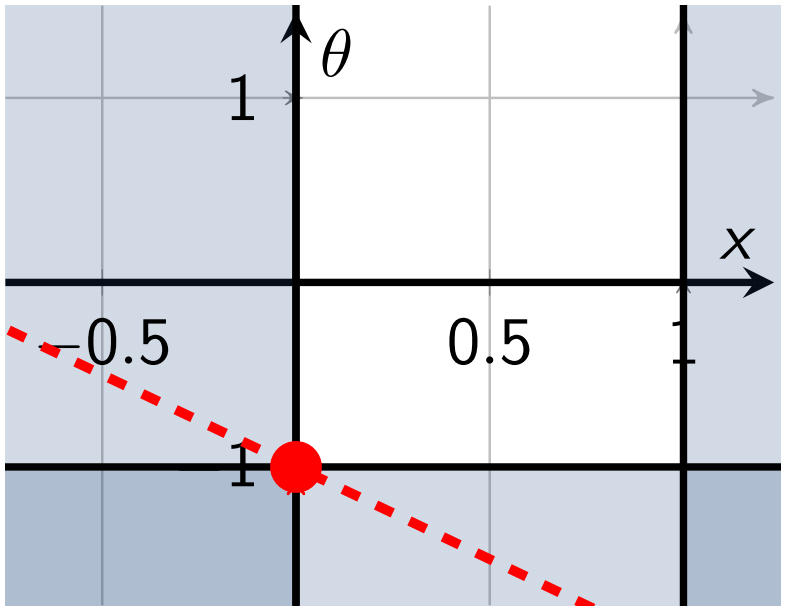

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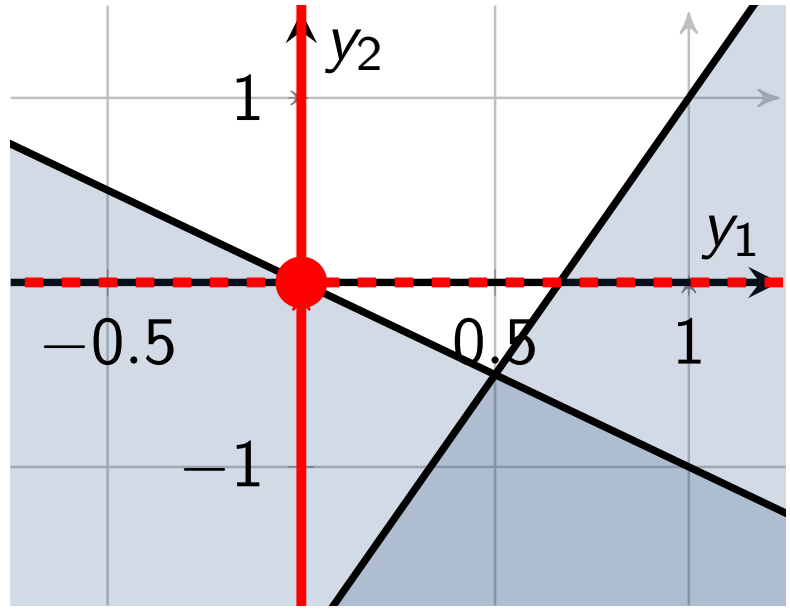

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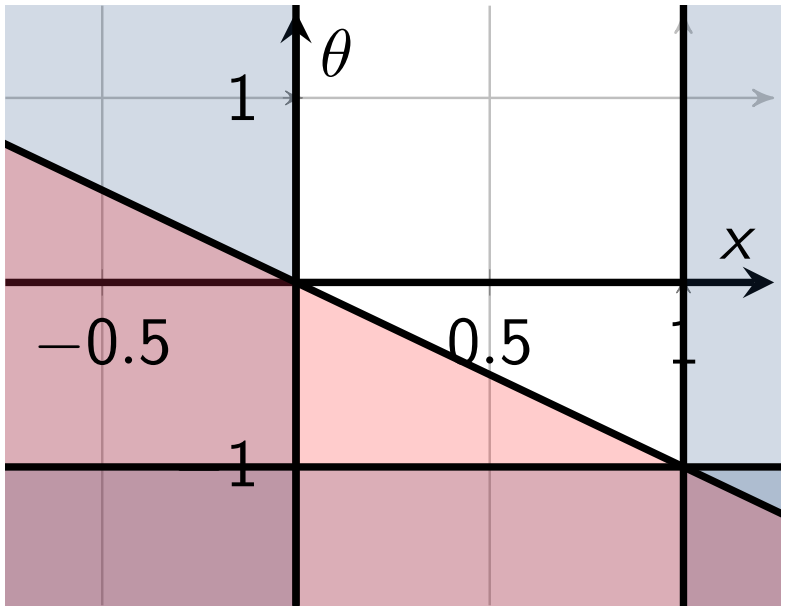

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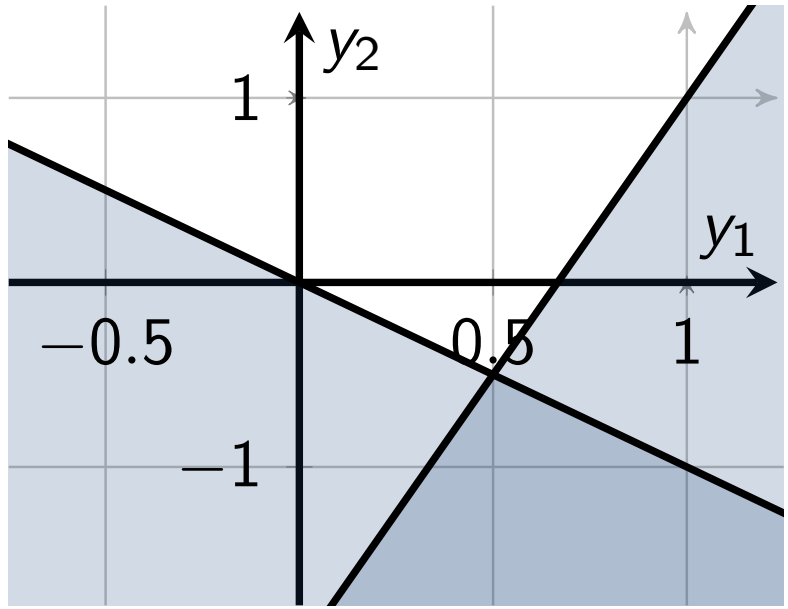
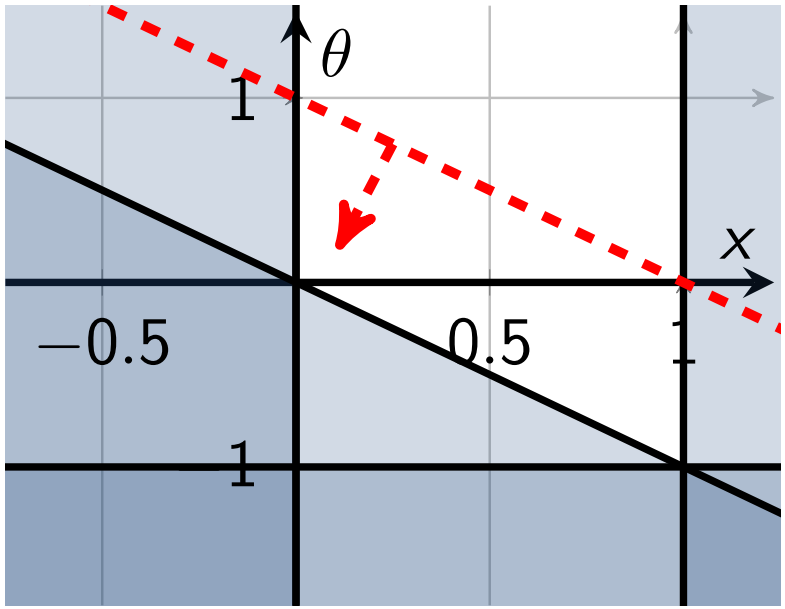
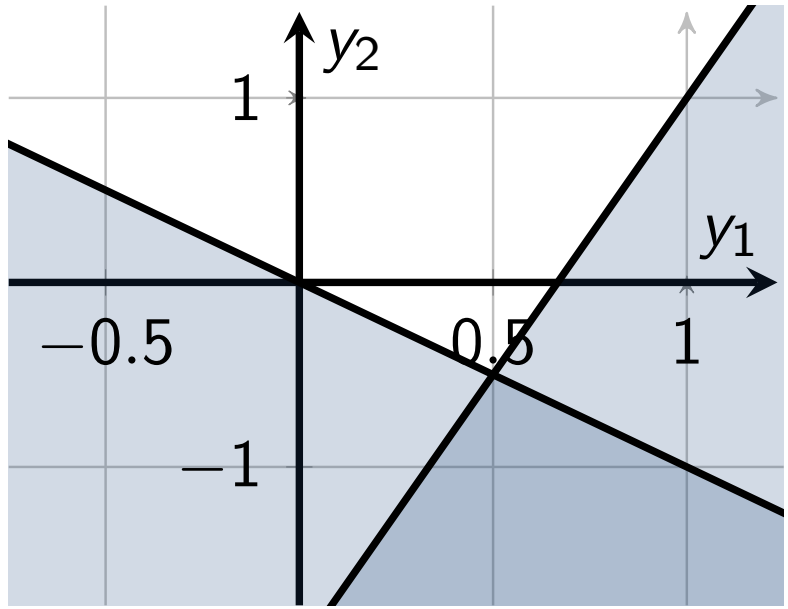


(b) Second Stage

Degeneracy

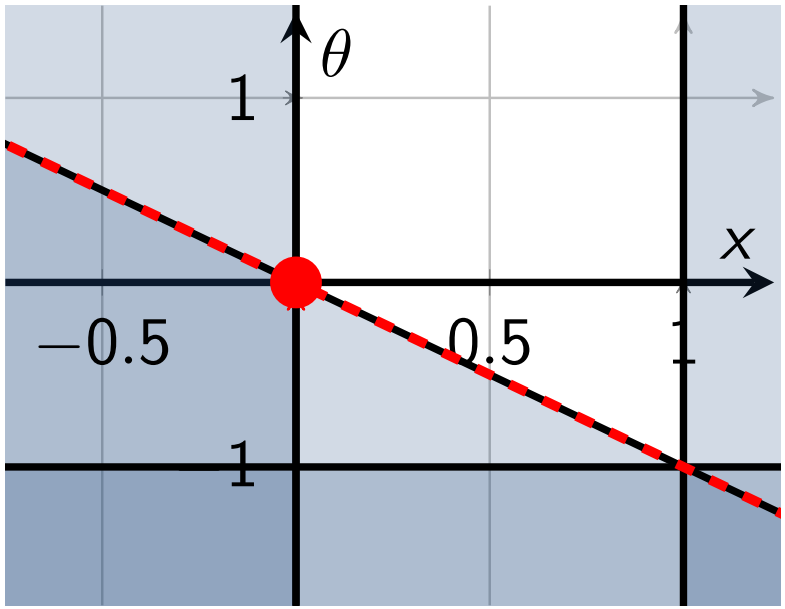


(a) First Stage

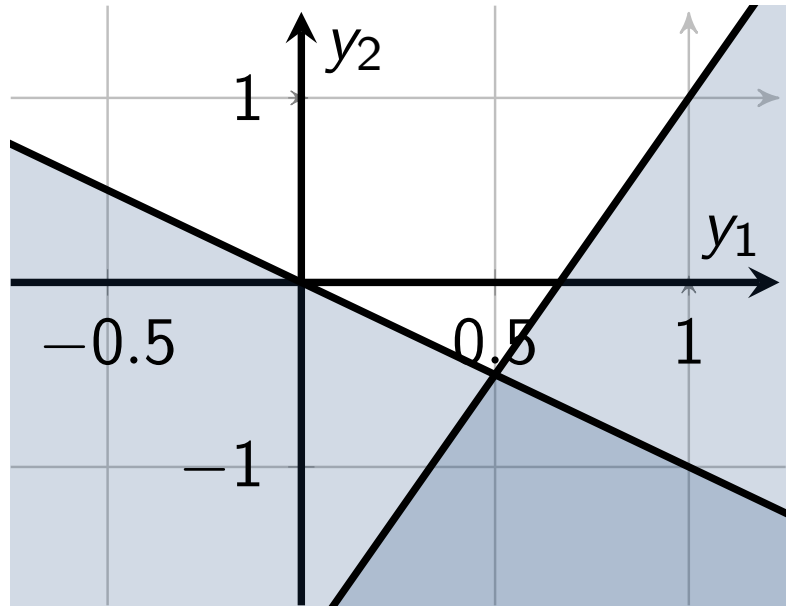


(b) Second Stage

Degeneracy

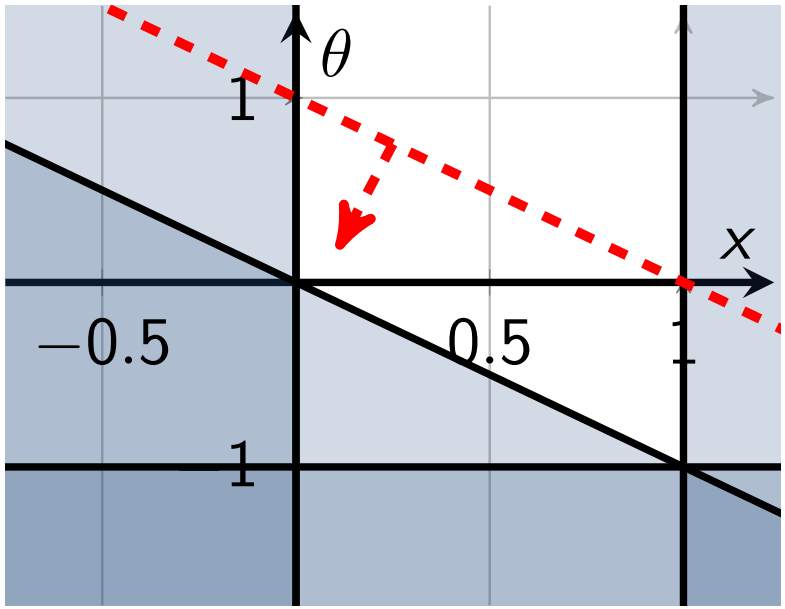


(a) First Stage



(b) Second Stage

Degeneracy



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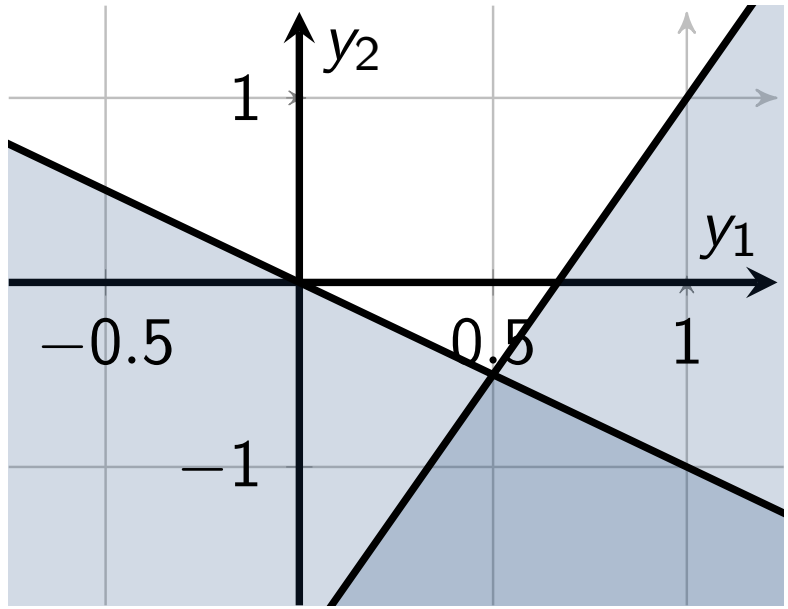
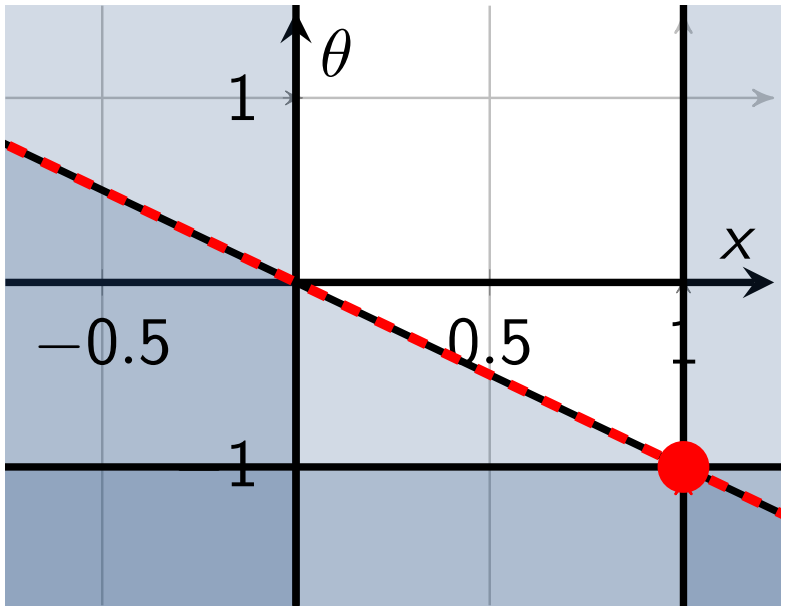


(b) Second Stage

Degeneracy



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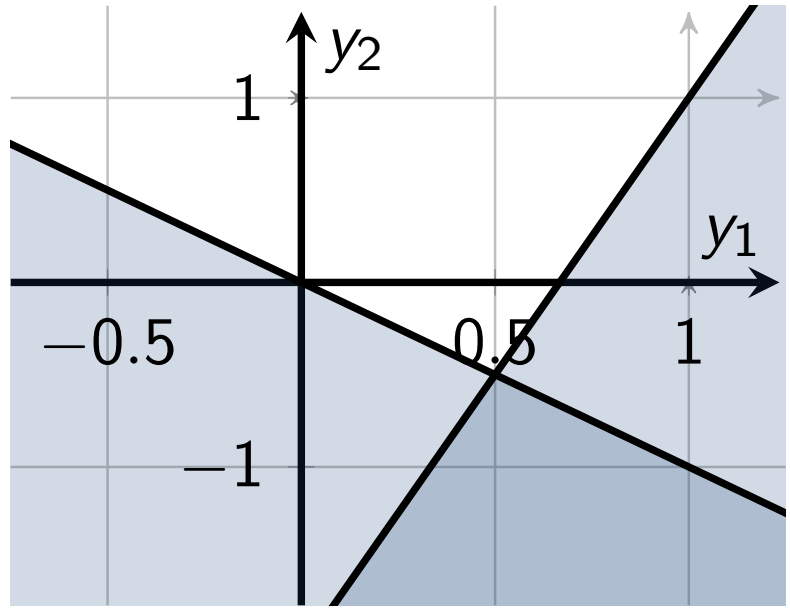
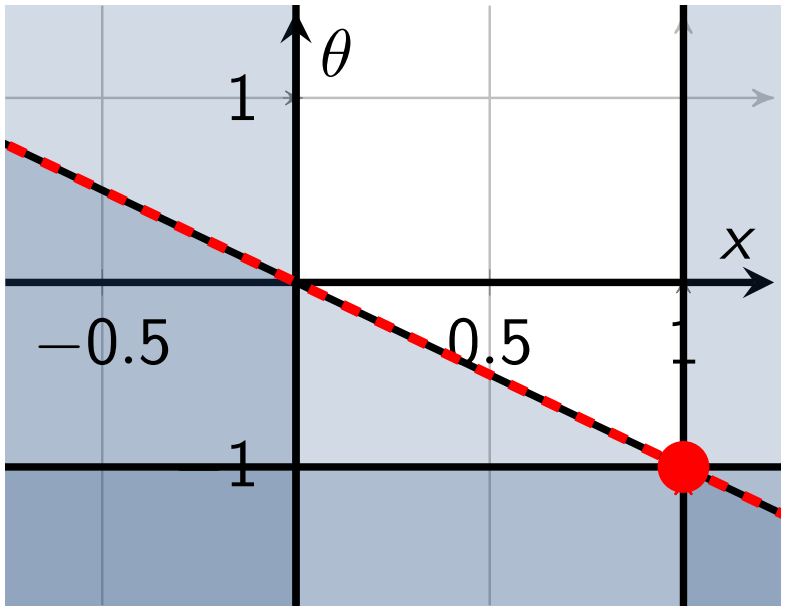


(b) Second Stage

Degeneracy



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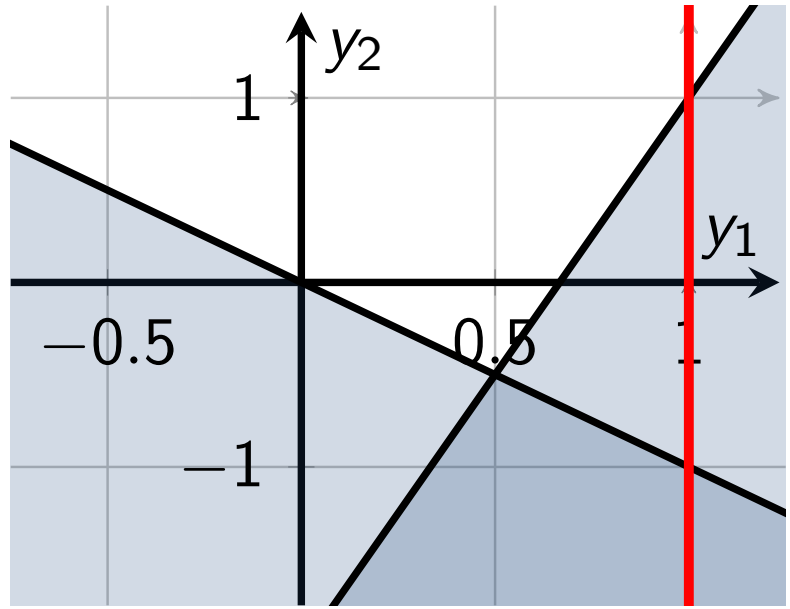
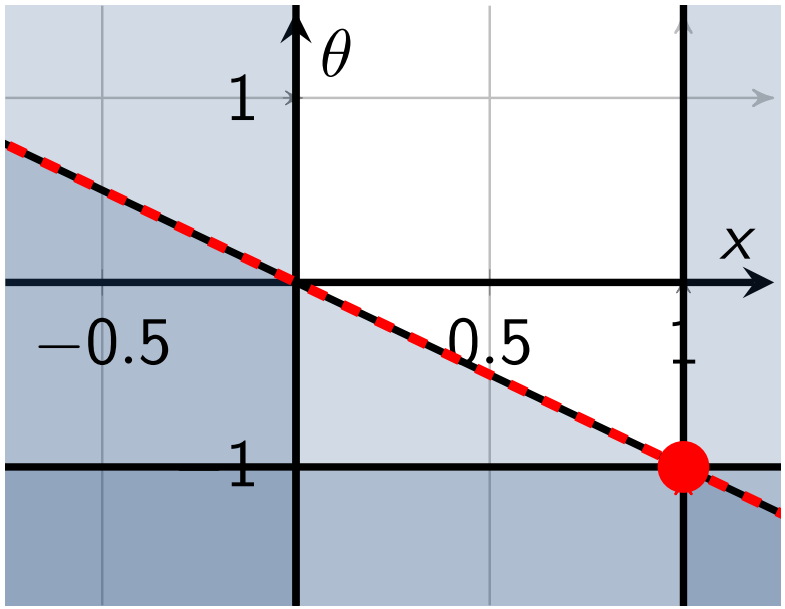


(b) Second Stage

Degeneracy



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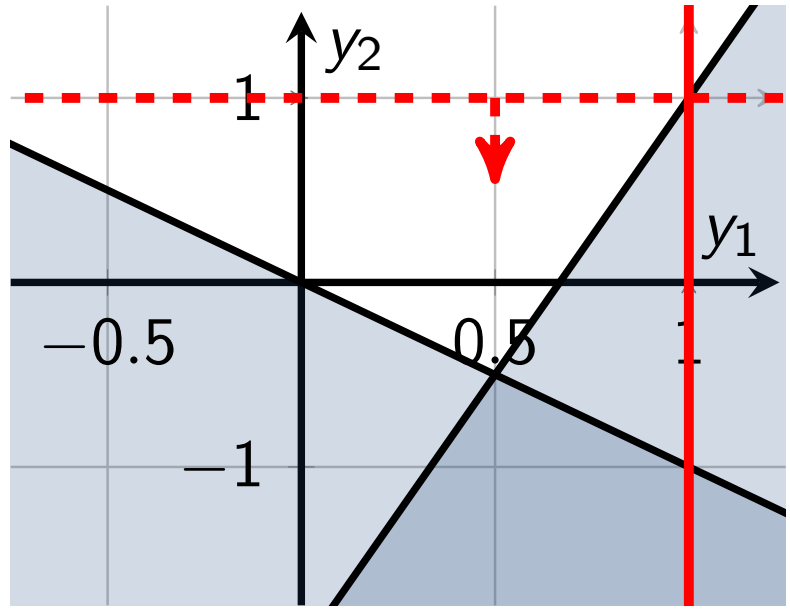
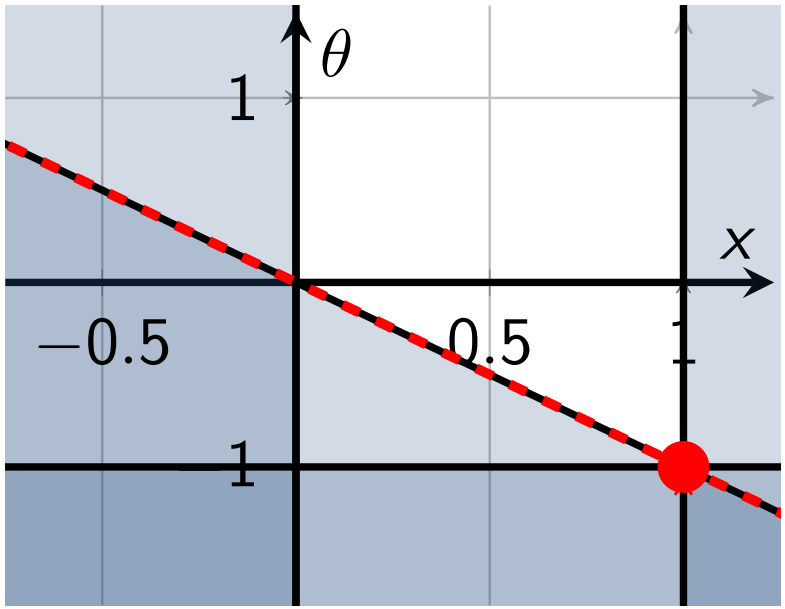


(b) Second Stage

Degeneracy



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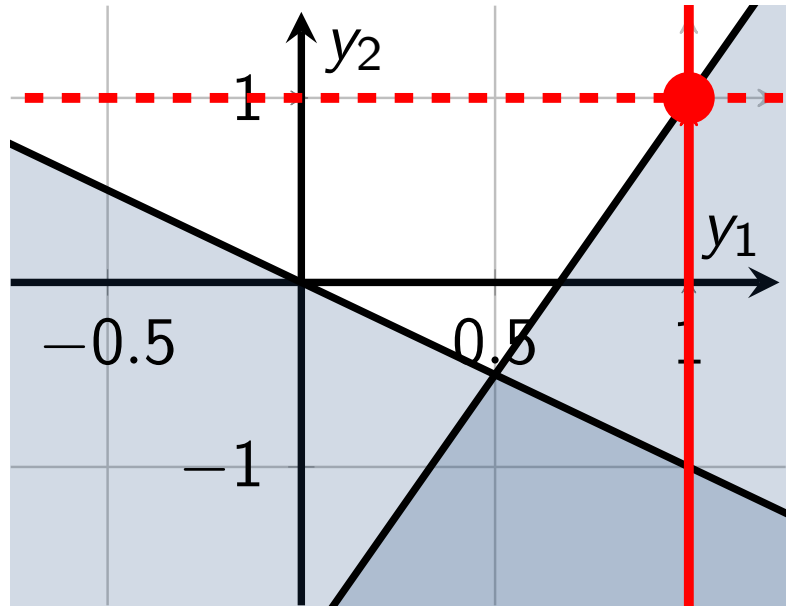

(b) Second Stage

Degeneracy

Implication for SDDP

When we simulate an "optimal" policy, we may obtain a sequence of sub-optimal controls, even in a converged, deterministic model.

More Open Questions

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