Replication of results in Larue, Pouliot and Singbo (2017)

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In this document I reproduce the results in Larue, Singbo, and Pouliot (2017), with their paper titled Production Rigidity, Input Lumpiness, Efficiency, and the Technological Hurdle of Quebec Dairy Farms. The Stata file `Rigidity_lumpiness_efficiency_hurdle.do` contains the code used in Larue, Singbo, and Pouliot (2017) to estimate stochastic frontier models.

All the material necessary to produce this document is available on my Github page at https://github.com/SebPouliot. This pdf document is generated by compiling the file `Replication of Larue, Pouliot & Singbo (2017).Rmd`.

I begin by generating the figures in the article that were produced using R. I then turn into preparing the data and then finally I estimate the results in the model.[1]

Figures

Figures 2, 3 and 4 were generated using R. Figure 2 and 3 use data from a survey of dairy farms in Québec. Figure 4 is based on functional forms and numerical solutions.

Figure 2

Figure 2 in the article (figure 1 in this document) uses the data available in the subfolder `Data` under the name `Quota trade.xlsx`. I save all figures into the subfolder `Figures` using the figure number.

```
# Load data
dta <- read_excel("Data/Quota trade.xlsx") %>%
    mutate(date = as.Date(time)) %>%
    rename(Price = price, `Price ceiling` = priceceiling)
################ Figure 2 ###
dta_graph <- dta %>% dplyr::select(date,
    Price, `Price ceiling`) %>% gather(var,
    price, c(Price, `Price ceiling`))
plot1 <- ggplot(dta_graph, aes(x = date,
    y = price, color = var)) + geom_line(size = 1) +
    scale_x_date(date_labels = "%Y",
        date_breaks = "year") + ylab("Price ('000 $CA)") +
```

[1] I had to use horizontable lines to separate sections and subsections of the document. Otherwise, the text extended beying the margin at the bottom for one page and I do not know what caused this.

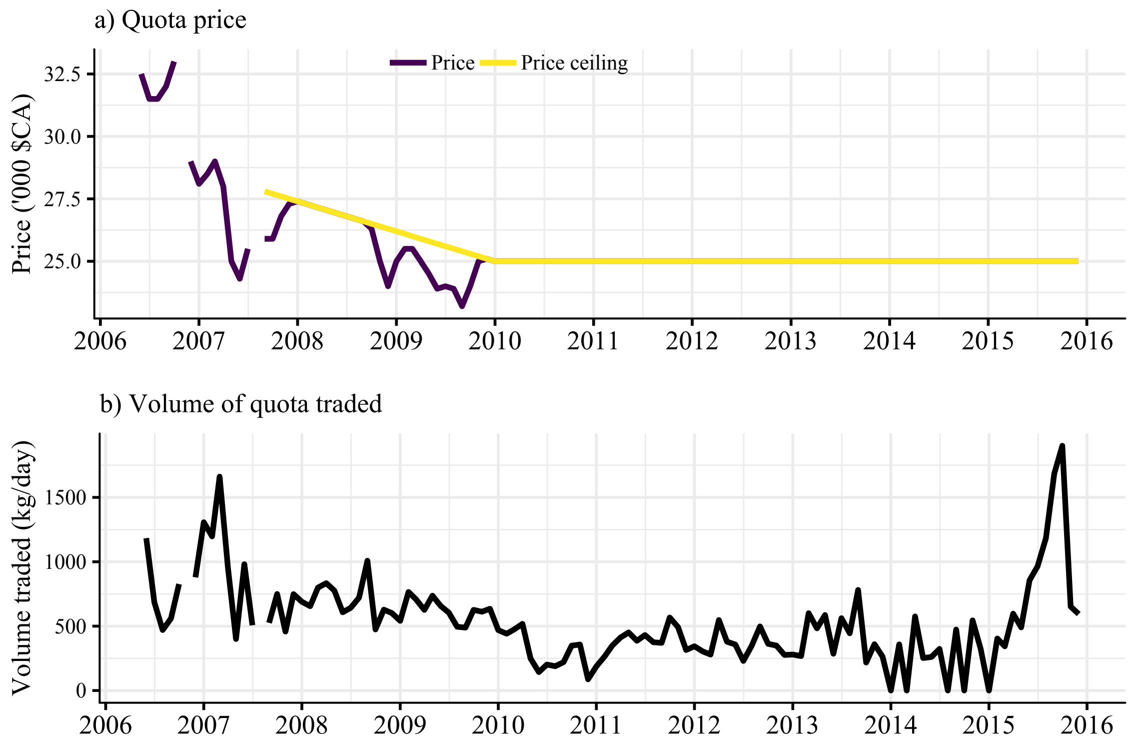

Figure 1: Prices (a) and volume traded (b) on Quebec's production quota exchange (Figure 2)

```
    scale_color_viridis(discrete = TRUE) +
    theme_bw() + mytheme + theme(legend.direction = "horizontal",
    legend.position = c(0.4, 0.95),
    axis.title.x = element_blank(),
    axis.line.x = element_line(color = "black"),
    axis.line.y = element_line(color = "black")) +
    labs(title = "a) Quota price")
plot2 <- ggplot(dta, aes(x = date, y = volumetraded)) +
    geom_line(size = 1) + scale_x_date(date_labels = "%Y",
    date_breaks = "year") + ylab("Volume traded (kg/day)") +
    theme_bw() + mytheme + theme(legend.direction = "horizontal",
    legend.position = c(0.4, 0.95),
    axis.title.x = element_blank(),
    axis.line.x = element_line(color = "black"),
    axis.line.y = element_line(color = "black")) +
    labs(title = "b) Volume of quota traded")
fig2 <- grid.arrange(plot1, plot2, ncol = 1,
    nrow = 2)
```

```
ggsave(fig2, filename = "Figures/Figure 2.png",
    width = 6, height = 6, units = "in",
    dpi = 600)
```

Figure 3

The data to produce figure 3 (figure 2 in this document) are the same as in those to create figure 2.

```
################ Figure 3 ###
dta_graph <- dta %>% dplyr::select(date,
    sellers, buyers) %>% rename(`Number of sellers` = sellers,
    `Number of buyers` = buyers) %>%
    gather(var, number, c(`Number of sellers`,
        `Number of buyers`))
fig3 <- ggplot(dta_graph, aes(x = date,
    y = number, color = var)) + geom_line(size = 1) +
    scale_x_date(labels = date_format("%Y"),
        breaks = date_breaks("year")) +
    scale_color_viridis(discrete = TRUE) +
    theme_bw() + mytheme + theme(legend.direction = "horizontal",
    legend.position = c(0.4, 0.95),
    axis.title.x = element_blank(),
    axis.line.x = element_line(color = "black"),
    axis.title.y = element_blank(),
    axis.line.y = element_line(color = "black"))
ggsave(fig3, filename = "Figures/Figure 3.png",
    width = 6, height = 4, units = "in",
    dpi = 600)
print(fig3)
```

Figure 4

Figure 4 (figure 3 in this document) uses functional forms and numerical values. The code below shows how to produce that figure.

```
# Produce data for graph
dta <- array(NA, c(2500, 1)) %>% tbl_df %>%
    rename(L = V1)
dta <- dta %>% mutate(L = seq(0, 250,
    length.out = nrow(dta))) %>% mutate(K_100 = 100^2/L,
    C_100 = 200 - 1 * L) %>% mutate(K_89 = (10 *
```

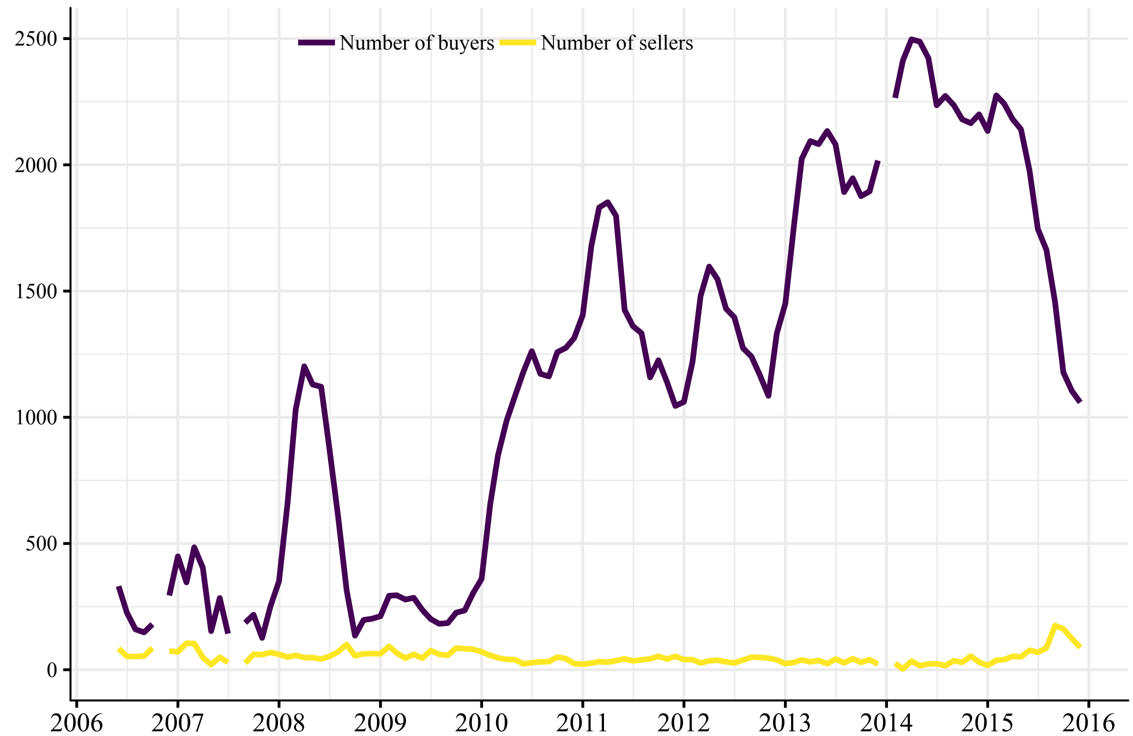

Figure 2: Number of buyers and sellers involved in production quota trades in Quebec (Figure 3)

```
    80^0.5)^2/L, C_89 = (200) - 1.25 *
    L) %>% mutate(K_71 = (10 * 50^0.5)^2/L,
    C_71 = (200) - 2 * L) %>% mutate(K_179 = (200^0.5 *
    160^0.5)^2/L, C_179 = (200 * 1 +
    160 * 1.25) - 1.25 * L) %>% mutate(K_141 = (200^0.5 *
    100^0.5)^2/L, C_141 = (200 * 1 +
    100 * 2) - 2 * L)
for (k in 2:ncol(dta)) {
    dta[dta[, k] > 250, k] <- NA
}
# Plot the lines
color_list <- viridis(5)
p <- ggplot() + geom_line(data = dta,
    aes(x = L, y = K_100), size = 1,
    color = color_list[1]) + geom_line(data = dta,
    aes(x = L, y = C_100), size = 1,
    color = color_list[1]) + geom_line(data = dta,
    aes(x = L, y = K_89), size = 1,
    color = color_list[2]) + geom_line(data = dta,
    aes(x = L, y = C_89), size = 1,
    color = color_list[2]) + geom_line(data = dta,
    aes(x = L, y = K_71), size = 1,
    color = color_list[3]) + geom_line(data = dta,
    aes(x = L, y = C_71), size = 1,
    color = color_list[3]) + geom_line(data = dta,
    aes(x = L, y = K_179), size = 1,
    color = color_list[4]) + geom_line(data = dta,
    aes(x = L, y = C_179), size = 1,
    color = color_list[4]) + geom_line(data = dta,
    aes(x = L, y = K_141), size = 1,
    color = color_list[5]) + geom_line(data = dta,
    aes(x = L, y = C_141), size = 1,
    color = color_list[5]) + geom_hline(yintercept = 100,
    linetype = 2) + geom_hline(yintercept = 200,
    linetype = 2) + scale_y_continuous(expand = c(0,
    0), limits = c(0, 250)) + scale_x_continuous(expand = c(0,
    0), limits = c(0, 250))
# Add labels
p <- p + annotate("text", x = 101, y = 106,
    label = "a", size = 4, family = "Times New Roman") +
    annotate("text", x = 81, y = 106,
        label = "b", size = 4, family = "Times New Roman") +
    annotate("text", x = 161, y = 206,
        label = "c", size = 4, family = "Times New Roman") +
```

```r
    annotate("text", x = 51, y = 106,
        label = "d", size = 4, family = "Times New Roman") +
    annotate("text", x = 101, y = 206,
        label = "e", size = 4, family = "Times New Roman") +
    annotate("text", x = 38, y = 245,
        label = "100", size = 2.5, family = "Times New Roman") +
    annotate("text", x = 28, y = 245,
        label = "89.44", size = 2.5,
        family = "Times New Roman") +
    annotate("text", x = 138, y = 245,
        label = "178.89", size = 2.5,
        family = "Times New Roman") +
    annotate("text", x = 15, y = 245,
        label = "70.71", size = 2.5,
        family = "Times New Roman") +
    annotate("text", x = 88, y = 245,
        label = "141.42", size = 2.5,
        family = "Times New Roman")
# Axis labels and theme
p <- p + ylab("Capital (K)") + ylab("Capital (K)") +
    xlab("Labor (L)") + theme_bw() +
    mytheme
ggsave(p, filename = "Figures/Figure 4.png",
    width = 6, height = 6, units = "in",
    dpi = 600)
p
```

Data

The paper explains that the data are a farm account series from the *Groupe Conseils Agricoles du Quebec*, a management group in the province of Quebec, and thus only members of this group are part of the sample. The table below defines the variables in the data. The variables `dbef2009` and `daft2009` are only used in robustness checks performed in the Stata `.do` file available on the Github repository.

Table 1: Definitions of variables

Name	Definition
labo	Labor quantity (fte)
feed	Value of feed input ($)
machi	Value of machinery input ($)
ocapi	Value of other capital ($)
vout1	Value of dairy output ($)

Name	Definition
otout1	Value of other output ($)
land	Land area (HA)
Age	Age of operator
north	Dummy variable for north region
south	Dummy variable for south region
offwork	Dummy for operator working off farm
dbef2009	Dummy for a farm observed only before 2009
daft2009	Dummy for a farm observed only affter 2009

In the chunk that follows, I create from the raw data the necessary columns to estimate regression models. The table below provides the definion of the variables in the database.

I save the data as `Clean data.xlsx` file and in Stata for as `Clean data.dta` in the `Data` folder.

```
dta <- read_excel("Data/Raw data.xlsx")
# Create data for estimation
dta <- dta %>% mutate(mland = log(land) -
    mean(log(land)), mland1 = -mland,
    mlvout1 = log(vout1) - mean(log(vout1)),
    mlotout1 = log(otout1) - mean(log(otout1)),
    mlfeed1 = log(feed) - mean(log(feed)) -
        mland, mlabo1 = log(labo) -
        mean(log(labo)) - mland, mlmach1 = log(machi) -
        mean(log(machi)) - mland, mlocapi1 = log(ocapi) -
        mean(log(ocapi)) - mland, mlvout2 = mlvout1^2,
    mlotout2 = mlotout1^2, mlfeed2 = mlfeed1^2,
    mlabo2 = mlabo1^2, mlmach2 = mlmach1^2,
    mlocapi2 = mlocapi1^2, lout12 = mlvout1 *
        mlotout1, out1_feed = mlvout1 *
        mlfeed1, out1_lab = mlvout1 *
        mlabo1, out1_mach = mlvout1 *
        mlmach1, out1_ocap = mlvout1 *
        mlocapi1, out2_feed = mlotout1 *
        mlfeed1, out2_lab = mlotout1 *
        mlabo1, out2_mach = mlotout1 *
        mlmach1, out2_ocap = mlotout1 *
        mlocapi1, feed_lab = mlfeed1 *
        mlabo1, feed_mach = mlfeed1 *
        mlmach1, feed_ocap = mlfeed1 *
        mlocapi1, lab_mach = mlabo1 *
        mlmach1, lab_ocap = mlabo1 *
        mlocapi1, mach_ocap = mlmach1 *
```

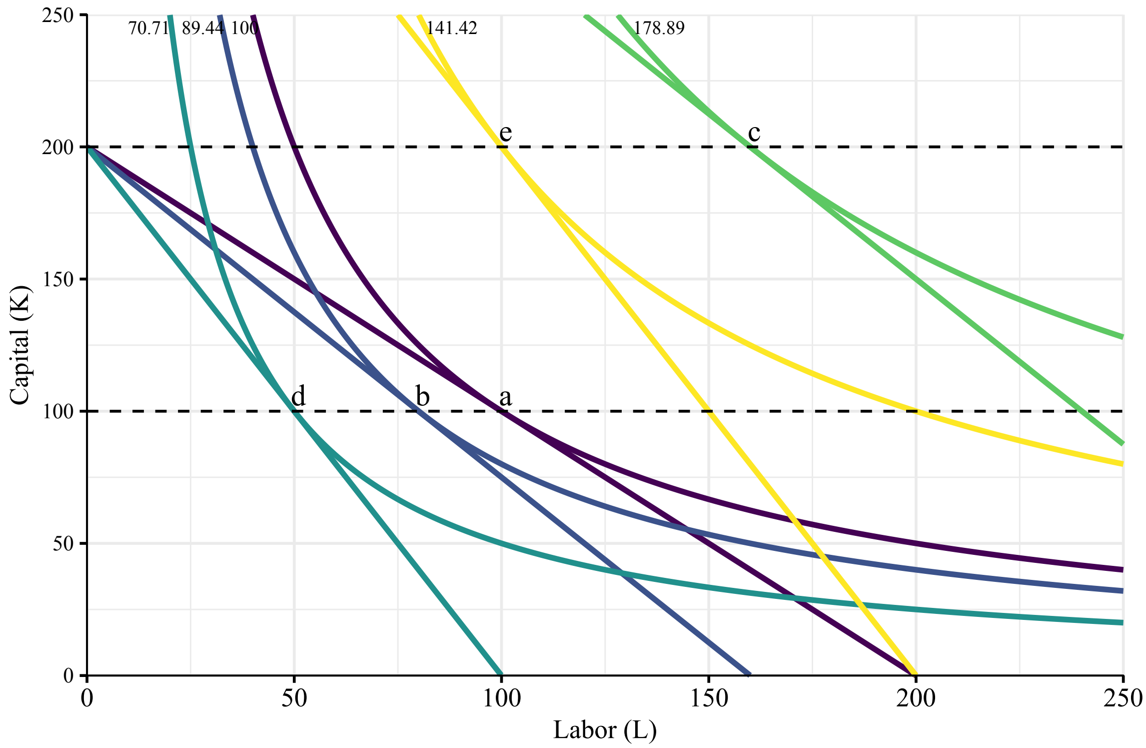

Figure 3: Input lumpiness and allocative efficiency (Figure 4)

```
        mlocapi1)
### Create the dummies and time trend
dta <- dta %>% mutate(time = year -
    2000, d2005 = as.numeric(year ==
    2005), d2006 = as.numeric(year ==
    2006), d2007 = as.numeric(year ==
    2007), d2008 = as.numeric(year ==
    2008), d2009 = as.numeric(year ==
    2009), d2010 = as.numeric(year ==
    2010), d2009a = as.numeric(year >=
    2009), t2009a = time * d2009a)
write.xlsx(data.frame(dta), "Data/Clean data.xlsx",
    sheetName = "Sheet1", col.names = TRUE,
    row.names = FALSE, append = FALSE)
write_dta(data.frame(dta), "Data/Clean data.dta",
    version = 14)
```

Table 2 summarizes the data.

```
table2 <- dta %>% dplyr::select(id,
    year, labo, feed, machi, ocapi,
    vout1, otout1, land, age, north,
```

```r
    south, offwork) %>% rename(`01) Labor` = labo,
    `02) Feed` = feed, `03) Machinery` = machi,
    `04) Other capital` = ocapi, `05) Dairy output` = vout1,
    `06) Other output` = otout1, `07) Land` = land,
    `08) Age` = age, `09) North` = north,
    `10) South` = south, `11) Off-farm work` = offwork) %>%
    gather(Variable, value, -c(year,
        id)) %>% group_by(Variable) %>%
    summarize(Mean = round(mean(value),
        2), P50 = round(median(value),
        2), SD = round(sd(value), 2)) %>%
    mutate(Units = c("Full time equivalent",
        "$", "$", "$", "$", "$", "HA",
        "Years", "Binary", "Binary",
        "Binary")) %>% dplyr::select(Variable,
    Units, Mean, P50, SD) %>% mutate(Mean = ifelse(Mean >=
    100, round(Mean, 0), Mean), P50 = ifelse(P50 >=
    100, round(P50, 0), P50), SD = ifelse(SD >=
    100, round(SD, 0), SD))
kable(table2, format = "latex", caption = paste0("Summary of selected ",
    "variables ", "(number of observations, N = 549)",
    "\\label{tab.summary}"), booktabs = T,
    linesep = "", align = c("l", "c",
        "c", "c", "c"), format.args = list(decimal.mark = ".",
        big.mark = ",")) %>% kable_styling(latex_options = c("striped",
    "hold_position"))
```

Table 2: Summary of selected variables (number of observations, N = 549)

Variable	Units	Mean	P50	SD
01) Labor	Full time equivalent	2.76	2.53	1.28
02) Feed	$	135,157.00	112,711.00	101,786.00
03) Machinery	$	299,589.00	241,365.00	236,385.00
04) Other capital	$	124,328.00	39,184.00	243,152.00
05) Dairy output	$	452,211.00	387,703.00	333,151.00
06) Other output	$	114,443.00	69,136.00	149,060.00
07) Land	HA	63.46	54.71	38.40
08) Age	Years	47.46	47.00	10.69
09) North	Binary	0.53	1.00	0.50
10) South	Binary	0.18	0.00	0.38
11) Off-farm work	Binary	0.16	0.00	0.37

Results

In the chunks below I reproduce the results in the paper. Several of the coefficients are reported in an appendix table in the paper. Below, the coefficient estimates for the production function and efficiency are all reported together in separate tables. I calculate average efficiency per period in a table on its own. Note that there small differences with the results in model reported in the paper because of a small difference in the way to define a dummy variable.

Model 1

Table 3 shows the results from model 1.

```
############### Model 1 ###
mod1 <- sf(mland1 ~ mlvout1 + mlotout1 +
    mlfeed1 + mlabo1 + mlmach1 + mlocapi1 +
    mlvout2 + mlotout2 + mlfeed2 + mlabo2 +
    mlmach2 + mlocapi2 + lout12 + out1_feed +
    out1_lab + out1_mach + out1_ocap +
    out2_feed + out2_lab + out2_mach +
    out2_ocap + feed_lab + feed_mach +
    feed_ocap + lab_mach + lab_ocap +
    mach_ocap, data = dta, distribution = c("t"),
    eff.time.invariant = TRUE, mean.u.0i = ~age +
        offwork + north + south + time +
        d2009a + t2009a, print.level = 0)
keep1 <- rownames(mod1$table)[!rownames(mod1$table) %in%
    c("logVv_intercept", "logVu_intercept",
        "lambda   ", "gamma   ", "sigma_v  ",
        "sigma_u  ")]
kable(mod1$table[keep1, ], format = "latex",
    longtable = T, booktabs = T, linesep = "",
    caption = "Results from model 1 \\label{tab.mod1}") %>%
    kable_styling("repeat_header", latex_options = "striped")
```

Table 3: Results from model 1

	Coef.	SE	z	P>|z|
intercept	0.3974	0.0178	22.36	0.0000
mlvout1	-0.7968	0.0150	-52.95	0.0000
mlotout1	-0.0481	0.0081	-5.96	0.0000
mlfeed1	0.6798	0.0229	29.74	0.0000
mlabo1	0.2675	0.0210	12.75	0.0000
mlmach1	0.0843	0.0146	5.77	0.0000
mlocapi1	0.0036	0.0033	1.09	0.2776

mlvout2	-0.1443	0.0217	-6.65	0.0000
mlotout2	-0.0053	0.0061	-0.87	0.3851
mlfeed2	0.0440	0.0590	0.75	0.4557
mlabo2	-0.0976	0.0440	-2.22	0.0267
mlmach2	0.0404	0.0238	1.70	0.0892
mlocapi2	-0.0016	0.0016	-1.00	0.3171
lout12	0.0543	0.0201	2.70	0.0069
out1_feed	0.1836	0.0619	2.97	0.0030
out1_lab	-0.2107	0.0583	-3.61	0.0003
out1_mach	0.0232	0.0418	0.56	0.5788
out1_ocap	0.0190	0.0090	2.12	0.0339
out2_feed	-0.0032	0.0301	-0.11	0.9156
out2_lab	0.0404	0.0273	1.48	0.1395
out2_mach	-0.0416	0.0207	-2.01	0.0443
out2_ocap	-0.0014	0.0049	-0.29	0.7727
feed_lab	0.0588	0.0900	0.65	0.5137
feed_mach	-0.0718	0.0598	-1.20	0.2298
feed_ocap	-0.0129	0.0140	-0.92	0.3587
lab_mach	0.0240	0.0577	0.42	0.6771
lab_ocap	0.0225	0.0129	1.74	0.0823
mach_ocap	-0.0129	0.0086	-1.50	0.1330
mu_intercept	0.2790	0.0356	7.83	0.0000
mu_age	0.0014	0.0005	2.94	0.0033
mu_offwork	-0.0317	0.0145	-2.18	0.0291
mu_north	0.0436	0.0133	3.28	0.0010
mu_south	0.0239	0.0154	1.54	0.1225
mu_time	-0.0053	0.0026	-2.08	0.0372
mu_d2009a	0.4898	0.1738	2.82	0.0048
mu_t2009a	-0.0362	0.0183	-1.98	0.0478

Model 2

Table 4 shows the results from model 2. Convergence is difficult in model 2 and setting the seed before estimating the model allows for the estimation to consistently converge to the same results as when using Stata.

```
############### Model 2 ###
set.seed(533573)
mod2 <- sf(mland1 ~ mlvout1 + mlotout1 +
    mlfeed1 + mlabo1 + mlmach1 + mlocapi1 +
    mlvout2 + mlotout2 + mlfeed2 + mlabo2 +
    mlmach2 + mlocapi2 + lout12 + out1_feed +
    out1_lab + out1_mach + out1_ocap +
```

```
    out2_feed + out2_lab + out2_mach +
    out2_ocap + feed_lab + feed_mach +
    feed_ocap + lab_mach + lab_ocap +
    mach_ocap + time, data = dta, distribution = c("t"),
    eff.time.invariant = TRUE, mean.u.0i = ~age +
        offwork + north + south + d2009a +
        t2009a, print.level = 0)
keep2 <- rownames(mod2$table)[!rownames(mod2$table) %in%
    c("logVv_intercept", "logVu_intercept",
        "lambda   ", "gamma   ", "sigma_v  ",
        "sigma_u  ")]
kable(mod2$table[keep2, ], format = "latex",
    caption = "Results from model 2 \\label{tab.mod2}",
    booktabs = T, linesep = "") %>%
    kable_styling("repeat_header", latex_options = "striped")
```

Model 3

Table 5 shows the results from model 3.

```
############### Model 3 ###
mod3 <- sf(mland1 ~ mlvout1 + mlotout1 +
    mlfeed1 + mlabo1 + mlmach1 + mlocapi1 +
    mlvout2 + mlotout2 + mlfeed2 + mlabo2 +
    mlmach2 + mlocapi2 + lout12 + out1_feed +
    out1_lab + out1_mach + out1_ocap +
    out2_feed + out2_lab + out2_mach +
    out2_ocap + feed_lab + feed_mach +
    feed_ocap + lab_mach + lab_ocap +
    mach_ocap, data = dta, distribution = c("t"),
    eff.time.invariant = TRUE, mean.u.0i = ~age +
        offwork + north + south + d2005 +
        d2006 + d2007 + d2008 + d2009 +
        d2010, print.level = 0)
keep3 <- rownames(mod3$table)[!rownames(mod3$table) %in%
    c("logVv_intercept", "logVu_intercept",
        "lambda   ", "gamma   ", "sigma_v  ",
        "sigma_u  ")]
kable(mod3$table[keep3, ], format = "latex",
    caption = "Results from model 3 \\label{tab.mod3}",
    booktabs = T, linesep = "") %>%
    kable_styling("repeat_header", latex_options = "striped")
```

Table 4: Results from model 2

	Coef.	SE	z	P>|z|
intercept	0.3707	0.0195	19.02	0.0000
mlvout1	-0.7967	0.0151	-52.93	0.0000
mlotout1	-0.0482	0.0081	-5.96	0.0000
mlfeed1	0.6799	0.0229	29.73	0.0000
mlabo1	0.2674	0.0210	12.75	0.0000
mlmach1	0.0843	0.0146	5.77	0.0000
mlocapi1	0.0036	0.0033	1.08	0.2786
mlvout2	-0.1443	0.0217	-6.65	0.0000
mlotout2	-0.0052	0.0061	-0.87	0.3864
mlfeed2	0.0441	0.0590	0.75	0.4551
mlabo2	-0.0976	0.0440	-2.22	0.0267
mlmach2	0.0404	0.0238	1.70	0.0892
mlocapi2	-0.0016	0.0016	-1.00	0.3169
lout12	0.0542	0.0201	2.70	0.0070
out1__feed	0.1835	0.0619	2.96	0.0030
out1__lab	-0.2106	0.0583	-3.61	0.0003
out1__mach	0.0232	0.0418	0.56	0.5783
out1__ocap	0.0190	0.0090	2.12	0.0339
out2__feed	-0.0031	0.0301	-0.10	0.9172
out2__lab	0.0404	0.0273	1.48	0.1398
out2__mach	-0.0416	0.0207	-2.01	0.0443
out2__ocap	-0.0014	0.0049	-0.29	0.7735
feed__lab	0.0587	0.0900	0.65	0.5140
feed__mach	-0.0718	0.0598	-1.20	0.2297
feed__ocap	-0.0129	0.0140	-0.92	0.3581
lab__mach	0.0240	0.0577	0.42	0.6771
lab__ocap	0.0225	0.0129	1.74	0.0823
mach__ocap	-0.0128	0.0086	-1.50	0.1334
time	0.0053	0.0025	2.08	0.0373
mu__intercept	0.2521	0.0325	7.75	0.0000
mu__age	0.0014	0.0005	2.94	0.0033
mu__offwork	-0.0317	0.0145	-2.18	0.0292
mu__north	0.0436	0.0133	3.28	0.0010
mu__south	0.0239	0.0155	1.55	0.1216
mu__d2009a	0.4897	0.1738	2.82	0.0048
mu__t2009a	-0.0362	0.0183	-1.98	0.0477

Table 5: Results from model 3

	Coef.	SE	z	P>|z|
intercept	0.3775	0.0180	20.94	0.0000
mlvout1	-0.8005	0.0144	-55.63	0.0000
mlotout1	-0.0498	0.0078	-6.42	0.0000
mlfeed1	0.7196	0.0226	31.87	0.0000
mlabo1	0.2571	0.0200	12.85	0.0000
mlmach1	0.0670	0.0142	4.71	0.0000
mlocapi1	0.0050	0.0032	1.57	0.1162
mlvout2	-0.1501	0.0208	-7.23	0.0000
mlotout2	-0.0031	0.0058	-0.54	0.5896
mlfeed2	0.0341	0.0565	0.60	0.5455
mlabo2	-0.0815	0.0420	-1.94	0.0524
mlmach2	0.0349	0.0227	1.54	0.1246
mlocapi2	-0.0010	0.0015	-0.69	0.4880
lout12	0.0614	0.0192	3.19	0.0014
out1_feed	0.2140	0.0593	3.61	0.0003
out1_lab	-0.2236	0.0556	-4.02	0.0001
out1_mach	0.0159	0.0398	0.40	0.6895
out1_ocap	0.0094	0.0086	1.08	0.2791
out2_feed	-0.0103	0.0287	-0.36	0.7188
out2_lab	0.0550	0.0261	2.11	0.0348
out2_mach	-0.0387	0.0198	-1.95	0.0506
out2_ocap	-0.0015	0.0047	-0.31	0.7549
feed_lab	0.0601	0.0860	0.70	0.4849
feed_mach	-0.0652	0.0571	-1.14	0.2529
feed_ocap	-0.0018	0.0134	-0.13	0.8955
lab_mach	0.0158	0.0550	0.29	0.7736
lab_ocap	0.0088	0.0124	0.71	0.4804
mach_ocap	-0.0107	0.0082	-1.31	0.1886
mu_intercept	0.2733	0.0335	8.15	0.0000
mu_age	0.0015	0.0005	3.22	0.0013
mu_offwork	-0.0282	0.0139	-2.03	0.0419
mu_north	0.0386	0.0127	3.04	0.0024
mu_south	0.0245	0.0148	1.65	0.0986
mu_d2005	-0.1127	0.0166	-6.79	0.0000
mu_d2006	-0.0719	0.0182	-3.95	0.0001
mu_d2007	-0.0490	0.0182	-2.68	0.0073
mu_d2008	0.0240	0.0194	1.24	0.2164
mu_d2009	0.1125	0.0176	6.38	0.0000
mu_d2010	0.0694	0.0173	4.02	0.0001

Table 6: Average technical efficiency per period

Model	Period	Mean	Min	Max
Model 1	Ave.eff. 2001-08	0.7136	0.54	1.00
Model 1	Ave.eff. 2009	0.6203	0.48	0.78
Model 1	Ave.eff. 2010	0.6447	0.46	0.87
Model 2	Ave.eff. 2001-08	0.7155	0.54	1.00
Model 2	Ave.eff. 2009	0.6073	0.47	0.76
Model 2	Ave.eff. 2010	0.6279	0.45	0.85
Model 3	Ave.eff. 2001-08	0.7247	0.55	1.00
Model 3	Ave.eff. 2009	0.6252	0.49	0.77
Model 3	Ave.eff. 2010	0.6509	0.48	0.87

Average technical efficiency per period

Table 6 report average efficiency per period.

```
eff1 <- cbind(mod1$efficiencies, year = dta$year) %>%
    mutate(Model = "Model 1")
eff2 <- cbind(mod2$efficiencies, year = dta$year) %>%
    mutate(Model = "Model 2")
eff3 <- cbind(mod3$efficiencies, year = dta$year) %>%
    mutate(Model = "Model 3")
eff <- rbind(eff1, eff2) %>% rbind(eff3)
eff <- eff %>% mutate(gyear = case_when(year %in%
    2001:2008 ~ "Ave.eff. 2001-08",
    year == 2009 ~ "Ave.eff. 2009",
    year == 2010 ~ "Ave.eff. 2010")) %>%
    group_by(Model, gyear) %>% summarize(Mean = round(mean(Mode),
    4), Min = round(min(`Lower bound`),
    2), Max = round(max(`Upper bound`),
    2)) %>% rename(Period = gyear)
kable(eff, format = "latex", caption = paste0("Average technical efficiency ",
    "per period \\label{tab.tech}"),
    booktabs = T, linesep = "", align = c("l",
        "l", "c", "c", "c"), format.args = list(decimal.mark = ".",
        big.mark = ",")) %>% kable_styling(latex_options = "striped")
```

References

Larue, Bruno, Alphonse Singbo, and Sebastien Pouliot. 2017. "Production Rigidity, Input Lumpiness, Efficiency, and the Technological Hurdle of Quebec Dairy Farms." *Canadian Journal of Agricultural Economics/Revue Canadienne d'agroeconomie* 65 (4): 613–41. https://doi.org/10.1111/cjag.12156.