Application of VECM on livestock production index, carbon dioxide damage, arable land, population growth, and GDP growth in Indonesia

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Abstract. Environmental effects due to carbon dioxide in Indonesia tend to increase and arable lands are shrinking. These things are accompanied by population and economic growth, making the need for food higher so that the livestock production index increases. After the economic crisis caused by the subprime mortgage, the livestock production index gradually recovered and increased consistently in 2009-2018. However, it turns out that the contribution of the livestock sector to the economy in 2011-2013 was still below the agricultural and plantation sectors. The purpose of this research was to analyze the cointegration and causality relationship of livestock production index, carbon dioxide damage, arable land, population growth, and GDP growth using the VECM method for time series data from 1970-2018. The results show that there was cointegration between variables. The causality test shows that population growth and carbon dioxide damage affect each other. Meanwhile, the livestock production index on population growth has a one-way causality pattern. Arable land on carbon dioxide damage also has a one-way causality pattern. In general, the VECM model shows that there is a long-term relationship between the variables that were used in this research.

1. Introduction
The environmental impact caused by carbon dioxide causes the cost of damage due to carbon dioxide emissions also tends to increase. Unfortunately, the environment that has been damaged a lot has also reduced the amount of arable land. Arable land has many uses such as providing fodder, growing more plants so it can absorb carbon dioxide emissions around it, and so on. Environmental problems also occur due to population growth and GDP. An increasing population and GDP can make the need for food increasing. Although population growth decreases, the number of populations in Indonesia tends to increase. GDP growth in Indonesia is relatively stable but the GDP tends to increase and makes the need for food increase and the purchasing power of the population to consume more expensive foods also increases. This can be seen from the livestock production index. Although the livestock production index had decreased when the subprime mortgage crisis occurred, the livestock production index in Indonesia gradually increased in 2009-2018 [1].

The increase in livestock production has succeeded in contributing to the GDP value and GDP share in the agricultural sector in 2013 by 12.9 percent [2]. This number is much higher than the livestock sector's contribution to the GDP value and GDP share of the agricultural sector in 2009. The workforce that works in the livestock sector in Indonesia in 2013 reached 1,856,875 people [2]. However, when
compared to other sectors, the livestock sector contribution to the economy is still under the agricultural and plantation sectors.

The role of the food crop agricultural sector is so large in the economy when compared to other agricultural sectors that many previous studies have analyzed the effect of carbon dioxide emissions on food crop production [3–5]. However, because the livestock production index in Indonesia tends to increase, this study focused on analyzing the cointegration and causality relationship of the livestock production index, carbon dioxide damage, arable land, population growth, and GDP growth. By using economic variables such as GDP growth, this study provides a new perspective not only on the effect of environmental variables on the livestock production index but also provides a new perspective on the effect of economic variables such as GDP growth on the livestock production index in Indonesia.

2. Literature review

The impact of environmental changes in living things had been analyzed by previous research. However, every study discussed it with different perspectives and purposes. For instance, research in Pakistan aimed to decouple the influence of carbon dioxide emissions on forestry production, crops production, livestock production, energy use, population growth, rainfall, and temperature using the VECM method. The results of the study indicate that forestry production, crops production, livestock production, population growth, rainfall, and temperature have constructive effects on carbon dioxide emission in Pakistan in the short term [4].

Other studies suggest that climate change has a negative impact on livestock production because climate change increases global warming which will increase more areas that are drought [6]. Furthermore, climate change also affects the nutritional content of livestock products and livestock production also affects climate change [6]. Carbon dioxide plays a role in climate change, but on the other hand carbon dioxide is also useful for the photosynthetic system of plants for fodder. However, many carbon dioxide can increase temperature and reduce the amount of fertile soil due to drought. Another study analyzed the relationship between climate change and food supply chains and stated that climate change affects the food supply chains, including the supply chain of livestock and the price of livestock products [7]. Arable land can grow natural fodder for livestock such as good quality grass. Furthermore, the fodder will also affect the nutrients contained in livestock. The production of livestock with good quality and great quantity will affect the selling price in the market and the welfare of the farmers.

Climate change not only affects the fodder, nutrition, and livestock prices but also affects the stress experienced by livestock, as previously stated by research conducted in South Africa [8]. One kind of animal that is sensitive to hot temperatures are dairy cows. Furthermore, previous research also stated that livestock production also tends to increase because a more prosperous economy increases the demand for livestock meat [8]. The income contribution of the livestock portfolio varies because it depends on the kind of animal being farmed, usually the kind of livestock that contributes the highest to income are goats followed by poultry [9].

3. Research methods

The data used in this study were annual time series data from 1970-2018. The data were secondary data obtained from the World Bank [1]. This research used five variables such as livestock production index, carbon dioxide damage, arable land, population growth, and GDP growth. This research used a quantitative approach. The data were tested using Vector Error Correction Model (VECM) to analyze the cointegration and causality relationship between the variables. VECM is also used to estimate short-term and long-term relationships between the variables. There were some stages in the VECM. First, the data was processed using the stationarity test then continued by using optimal lag/lag length test, stability test, cointegration test, causality test, VECM, Impulse Response Function (IRF), and variance decomposition. The general model of equation in this research based on Hidayat [10] as follow:
\[
LPI_t = a_0 + \sum_{j=1}^{n} a_1 LPI_{t-j} + \sum_{j=1}^{n} a_2 CDD_{t-j} + \sum_{j=1}^{n} a_3 AL_{t-j} + \sum_{j=1}^{n} a_4 PG_{t-j} + \sum_{j=1}^{n} a_5 GG_{t-j} + \mu_1 t
\]

Where:
- LPI = Livestock Production Index
- CDD = Carbon Dioxide Damage
- AL = Arable Land
- PG = Population Growth
- GG = GDP Growth
- a = Constant
- \(\mu\) = Error term
- j = Lag
- t = Time trend

4. Results and discussion

Based on the results of the unit root test using the Augmented Dickey Fuller (ADF) test, it can be seen that only the GDP growth variable was stationary at the level stage, so it was necessary to do a differential. After doing the differential, all the variables used in this study were stationary at the first difference level with \(\alpha=5\%\). The optimal lag test/lag length results show that the optimal lag in this study is at lag 2. Furthermore, the stability test results show that all variables pass the stability test because based on the inverse roots of AR Characteristic Polynomial, it shows that all points are inside the circle. In addition, there is no modulus value above 1 so that the VAR is already in a stable condition.

The cointegration test in this study used the Johansen Cointegration Test (JCT) where to see the cointegration between variables, the trace statistic and Max-Eigen statistics need to be compared with the critical value. Based on the JCT results, it can be seen that the trace statistic value is greater than the critical value at none, at most 1, and at most 2 while the Max-Eigen statistic value is greater than the critical value when at none and at most 1 so that it can be concluded that there is cointegration between variables.

The results of the causality test show that carbon dioxide damage (CDD) has no effect on livestock production index (LPI), and vice versa. Arable land (AL) has no effect on livestock production index, and vice versa. Meanwhile, the livestock production index on population growth (PG) has a one-way causality pattern because population growth has no effect on livestock production index but livestock production index has an effect on population growth. GDP growth (GG) has no effect on livestock production index, and vice versa. Arable land has an effect on carbon dioxide damage but carbon dioxide damage has no effect on arable land so arable land on carbon dioxide damage has a one-way causality pattern. Population growth has an effect on carbon dioxide damage and carbon dioxide damage has an effect on population growth. GDP growth has no effect on carbon dioxide damage, vice versa. Population growth does not affect the arable land, and vice versa. GDP growth does not affect the arable land, and vice versa. GDP growth also has no effect on population growth, and vice versa.

The equation that can be written from the VECM results is:
\[
D(LPI) = -36.33545 - 2.345275 D(CDD) - 1166.006 D(AL) + 99.83555 D(PG) - 11.64719 D(GG) + \mu_1 t
\]

The constant value -36.33545 with negative value is an estimation of the livestock production index. If carbon dioxide damage, arable land, population growth, and GDP growth are considered constant, the livestock production index in Indonesia will decrease on average by -36.33545. The value of carbon dioxide damage is -2.345275 with a negative value, meaning that if carbon dioxide damage increases by 1 percent, there will be a decrease in livestock production index by -2.345275 with the assumption...
that arable land, population growth, and GDP growth are considered constant. The value of arable land is -1166.006 which is negative, meaning that if arable land increases by 1 percent, there will be a decrease in livestock production index of -1166.006 with the assumption that carbon dioxide damage, population growth, and GDP growth are considered constant. The population growth value is 99.83555 which is positive, meaning that if the population growth increases by 1 percent, there will be an increase in the livestock production index of 99.83555 with the assumption that carbon dioxide damage, arable land, and GDP growth are considered constant. GDP growth value is -11.64719 negative value, meaning that if GDP growth increases by 1 percent, there will be a decrease in livestock production index by 11.64719 assuming carbon dioxide damage, arable land, and population growth are considered constant.

Based on Table 1, VECM estimation results show that partially arable land, population growth, and GDP growth have a significant effect on livestock production index in the long term. This is because the t statistic is greater than the t table (2.021).

Table 1. Statistical values of the vector error correction model in the long-term

| Variable | Coefficient | T-stats | Information |
|----------|-------------|---------|-------------|
| CDD      | -2.345275   | -0.38051| Not significant |
| AL       | -1166.006   | -3.48583| Significant |
| PG       | 99.83555    | 6.66285 | Significant |
| GG       | -11.64719   | -7.31008| Significant |

Source: Processed data, 2021

In the long term, carbon dioxide damage has no significant effect on livestock production index. Arable land affects livestock production index. Arable land can grow crops for animal feed. However, the results in this study indicate that if the arable land increases, there will be a decrease in the livestock production index, if the arable land decreases then there will be an increase in the livestock production index. Arable land has a negative relationship with the livestock production index because the land used for livestock land will decrease. Usually, land used for livestock also has an impact on the environment. Then, although the amount of arable land is decreasing, the livestock production index can also increase because fodder is not only made from plants, there are also livestock that eat agricultural waste. Fodder can also be grown on less fertile soil. Population growth has a significant positive effect on the livestock production index because the more human population, the need for food from livestock also increases. GDP growth has a significant negative effect on livestock production index. This is not because the richer a person is, the consumption of their livestock decreases, but GDP growth is very difficult to increase every year, especially if a country is already in a stable condition or in a steady state condition. However, although GDP growth does not increase every year, GDP tends to increase so that people still consume livestock.

Based on Table 2, VECM estimation results show that in the short-term only the GDP growth has a significant effect on the livestock production index. Then, in the short-term, last year's arable land affected the livestock production index. In the short-term, population growth last year and two years ago affected the livestock production index. LPI one year ago also affected the livestock production index.

The results of the Impulse Response Function (IRF) show that the response given by carbon dioxide damage to the livestock production index after a shock shows a positive response. The shocks that occurred in the arable land to the livestock production index showed a negative response until the third period but in the fourth period until the final period showed an increase. The response given by population growth to the livestock production index after shocks showed a positive response. The shocks that occurred in GDP growth on the livestock production index showed a positive response from the first to the third period. Then, it decreased in the fourth period and slowly increased until it finally moved to a point of balance in the sixth period to the end of the period.
Table 2. Statistical values of the vector error correction model in the short-term

| Error Correction: | D(LPI) | D(CDD) | D(AL) | D(PG) | D(GG) |
|-------------------|--------|--------|-------|-------|-------|
| CountEq1          | 0.019586 | 0.000160 | 5.01E-05 | -6.16E-05 | 0.087066 |
|                   | (0.02915) | (0.00369) | (3.6E-05) | (3.9E-05) | (0.03289) |
|                   | [0.67191] | [0.04345] | [1.39211] | [-1.58359] | [2.64742] |
| D(LPI(-1))        | 0.115554 | 0.001567 | 0.000267 | -2.97E-05 | 1.33E-05 |
|                   | (0.17467) | (0.02211) | (0.00022) | (0.00023) | (0.19706) |
|                   | [0.66157] | [0.07088] | [1.23738] | [-0.12738] | [6.8e-05] |
| D(LPI(-2))        | -0.015427 | -0.011062 | 8.47E-05 | -0.000301 | -0.022660 |
|                   | (0.17334) | (0.02195) | (0.00021) | (0.00023) | (0.19556) |
|                   | [-0.08900] | [-0.50405] | [0.39608] | [-1.30135] | [-0.11587] |
| D(CDD(-1))        | 0.864899 | -0.139618 | 0.000312 | 0.002960 | -1.149543 |
|                   | (2.15914) | (0.27336) | (0.00266) | (0.00288) | (2.43590) |
|                   | [0.40058] | [-0.51075] | [0.11705] | [1.02787] | [-0.47192] |
| D(CDD(-2))        | 2.391303 | -0.404398 | 0.001514 | 0.002254 | -1.457897 |
|                   | (2.13209) | (0.26993) | (0.00263) | (0.00284) | (2.40539) |
|                   | [1.12158] | [-0.49814] | [0.57571] | [0.79247] | [0.60610] |
| D(AL(-1))         | -243.1553 | 13.84396 | 0.334708 | 0.432118 | -76.08649 |
|                   | (128.769) | (16.3028) | (0.15886) | (0.17175) | (145.275) |
|                   | [-1.88831] | [0.84918] | [2.10697] | [2.51600] | [-0.52374] |
| D(AL(-2))         | 63.71425 | -0.486804 | -0.201766 | -0.001445 | -40.01090 |
|                   | (127.034) | (16.0831) | (0.15672) | (0.16943) | (143.318) |
|                   | [0.50155] | [0.03027] | [-1.28746] | [-0.00853] | [-0.27918] |
| D(PG(-1))         | -28.39092 | -6.699253 | -0.058934 | 1.676048 | 97.12844 |
|                   | (68.2977) | (8.64682) | (0.08426) | (0.09109) | (77.0524) |
|                   | [-0.41569] | [-0.77476] | [-0.69946] | [18.3993] | [1.26055] |
| D(PG(-2))         | 56.58969 | 0.357218 | 0.074446 | -0.759523 | -97.94708 |
|                   | (71.8776) | (9.10005) | (0.08867) | (0.09587) | (81.0911) |
|                   | [0.78731] | [0.03925] | [0.43958] | [-7.92259] | [-1.20786] |
| D(GG(-1))         | 0.390510 | 0.010490 | 0.000245 | -0.000250 | 0.199729 |
|                   | (0.25947) | (0.03285) | (0.00032) | (0.00035) | (0.29273) |
|                   | [1.50505] | [0.31932] | [0.76601] | [-0.72113] | [0.68231] |
| D(GG(-2))         | 0.345677 | -0.005058 | 6.94E-05 | -3.51E-05 | -0.065331 |
|                   | (0.20665) | (0.02616) | (0.00025) | (0.00028) | (0.23314) |
|                   | [1.67275] | [-0.19334] | [0.27215] | [-0.12753] | [-0.28022] |
| C                 | 2.421667 | -0.132531 | -0.001230 | -0.001675 | -0.056127 |
|                   | (0.96979) | (0.12278) | (0.00120) | (0.00129) | (1.09411) |
|                   | [2.49710] | [-1.07941] | [-1.02825] | [-1.29459] | [-0.05130] |

Source: Processed data, 2021

The results of the variance decomposition analysis showed that the livestock production index showed the highest contribution while other variables had not contributed in the first period. Furthermore, livestock production index contributed 94.25 percent, carbon dioxide damage contributed 0.12 percent, arable land contributed 5.39 percent, population growth contributed 0.0008 percent, and
GDP growth contributed 0.25 percent in the second period. In the tenth period, livestock production index contributed 87.20 percent, carbon dioxide damage contributed 5.37 percent, arable land contributed 5.27 percent, population growth contributed 1.92 percent, and GDP growth contributed 0.24 percent.

5. Conclusion
Based on the results of the study, it can be concluded that there is cointegration between the variables used in this study. The results of the causality test showed that population growth has no effect on livestock production index but livestock production index has an effect on population growth. Arable land has an effect on carbon dioxide damage but carbon dioxide damage has no effect on arable land. Population growth has an effect on carbon dioxide damage and carbon dioxide damage has an effect on population growth. The results of the VECM test show that partially arable land, population growth, and GDP growth affect the livestock production index in the long-term. GDP growth has a significant effect on the livestock production index in the short-term.

The policies needed to increase the livestock production index in Indonesia are carrying out sustainable economic development such as providing animal feed from waste, reforesting damaged land, and regulating the pattern of maintenance and prices of livestock so that the quality and quantity of production is guaranteed. In addition, waste from livestock also needs to be recycled so that it can be more useful and not pollute the environment.

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